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PREFACE

The National Ecology Research Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This study is one of that series. It is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure using vegetation to designate wetlands based on the indicator status of wetland vegetation as described by the FWS "National List of Plants that Occur in Wetlands" (Reed, 1986). This list classifies all vascular plants of the U.S. into one of five categories according to their natural frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the Soil Conservation Service (SCS) developed the "National List of Hydric Soils" (SCS, 1985a). Studies supported by the National Ecology Research Center quantitatively compare associations of plant species, designated according to their hydric nature using the Wentworth and Johnson (1986) procedure, with the hydric soils list. The studies are being conducted across moisture gradients at a variety of wetland sites throughout the U.S. Several studies have been modified to obtain information on groundwater hydrology.

These studies were conceived in 1984 and implemented in 1985 in response to internal planning efforts of the FWS. They parallel, to some extent, ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1985 (the swampbuster provision). The SCS and FWS provided joint guidance and direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS is currently testing a procedure that combines hydric soils and the Wentworth and Johnson procedure for practical wetland delineation. The efforts of both agencies are complimentary and are being conducted in close cooperation.

The primary objectives of these studies are to (1) assemble a quantitative data base of wetland plant community dominance and codominance for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) test, in some instances, the correlation with groundwater hydrology. The results of these studies can also be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the Corps of Engineers (1987) and the Environmental Protection Agency (Sipple, 1987).

Any questions or suggestions regarding these studies should be directed to: Charles Segelquist, 2627 Redwing Road, Creekside One Building, Fort Collins, CO 80526-2899, phone FTS 323-5384 or Commercial (303) 226-9384.

SUMMARY

The soil properties and plant communities were studied on six soil series listed in the Hydric Soils of the State of South Dakota -- 1985, one hydric soil not listed, and three upland soils. The field study was conducted during the summer and fall of 1986. The objectives of the study were to test the premise that hydric soils support wetland plant communities and to verify the appropriateness of the soils for hydric designation.

Vegetation data were collected on ten plots from each of four replications of each soil. Plant community data were analyzed using the methodology developed at North Carolina State University for the National Wetland Inventory. Both the weighted average (WA) method and unweighted average (UA) method were used. These methods produce a community value that ranges on a scale of 1 to 5. In theory, values less than 3.0 are wetland and those above it are upland. However, previous studies have suggested that on a practical basis those values less than 2.5 are considered wetland, greater than 3.5 are upland. Values in between are considered to be inconclusive (the "gray area"). Both methods were used to analyze the vegetation data two ways: (1) using the National Wetland Inventory's indicator ratings, and (2) using these ratings but changing the ratings on ten species that were believed to be incorrect for this area and excluding facultative species from analysis. Three hydric soils and one upland soil were studied in Beadle County, South Dakota in the James River Lowland. Four hydric soils and two upland soils were studied in Deuel County, South Dakota in the Prairie Coteau.

Information on the morphological and chemical characteristics of the soils was collected on the four replications of each soil using standard methodology. The soil morphological data indicated that all six soils studied that were on the hydric soils list plus the seventh hydric soil (Southam) which was not listed, were hydric soils according to the criteria of the National Technical Committee for Hydric Soils. The three upland soils studied (Barnes, Hand, and Svea) were not hydric soils as defined by the criteria. Although soil morphological data indicate that ponding and watertable height duration qualify these soils to be listed, these conditions do not always occur in every growing season. A long-term frequency of occurrence of ponding and high watertable conditions needs to be included in the hydric soils criteria. It is suggested that 50 percent (five out of ten years), the same frequency listed in the criteria for flooding, may be realistic for this region. The criteria currently listed for the duration of ponding or watertable heights are probably realistic.

Results of all four methods of the vegetation analyses showed that the upland soils all supported upland plant communities. Of the seven

hydric soils; Parnell, Southam, Tetonka, and Worthing soils supported wetland plant communities. The Southam soil series should therefore be placed on the hydric soil list for South Dakota. Three hydric soils, Flom, Hoven, and Vallers were "problem" soils and all occurred at the wetland-upland interface. The Flom soil, regardless of method of analysis, supported upland plant communities. Two of the Hoven replications supported upland plant communities and two supported wetland communities resulting in the mean of the four replicates placed this soil in the "gray area". Use of our suggested changes in ten species' indicator ratings (and excluding facultative species) caused the plant community values of all hydric soils, except Flom, to drop slightly in value but not enough to move the means of the "problem" soils out of the "gray area" and down into the wetland category.

Analysis of variance (Waller-Duncan test) of plant community values showed that the Flom soil community was not significantly different from that of upland soil. The means of the other six hydric soils were significantly different from the upland soils. The means of these soils fell into two groups of three when the suggested revised ratings (with facultative species excluded) were used; the two "gray area" soils and the Tetonka soil were similar and were significantly different from the other three.

Methods used for vegetation analysis appear sound; however a critical revision of the species ratings used by the National Wetland Inventory may be needed. Species that do not yield useful information, such as facultative species, should be excluded from analysis. Because many wetlands in this region are cultivated, thus destroying natural vegetation, and because natural wetland plant communities are dynamic, the use of soils to delineate wetlands should be the method of choice. However, soil surveys for this region are not published at a scale that contains sufficient detail to identify most wetlands. Studies similar to the one reported here should be continued for the remaining 64 soils on the South Dakota list as well as those on the North Dakota and Minnesota lists. This would distinguish those soils that are obviously hydric in character from those that need further study. Additional studies of the soils occurring at the wetland-upland interface need to be conducted to determine if edge soils can be used to accurately delimit the wetland boundary.

CONTENTS

FIGURES

TABLES

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INTRODUCTION

Federal agencies need definitive criteria to designate wetlands and differentiate them from upland habitats. Definitive criteria would be extremely valuable in the implementation of the Fish and Wildlife Coordination Act, the National Environmental Policy Act, and the "Swampbuster" provisions of the 1985 Farm Bill. To this end, the U.S. Fish and Wildlife Service (FWS), in cooperation with other agencies, has developed a Wetland Plant List (WPL) (Reed, 1986) for the United States that rates each species according to its habitat indicator value. Generally, the indicator ratings fall into five categories:

(1) Obligate hydrophytes: species always found in wetlands under natural conditions (frequency > 99%).

(2) Facultative wetland plants: species usually found in wetlands (67% to 99% frequency).

(3) Facultative plants: species sometimes found in wetlands (34% to 66% frequency).

(4) Facultative upland plants: species seldom found in wetlands (1% to 33% frequency).

(5) Obligate upland plants: species not found in wetlands.

Wentworth and Johnson (1986) tested quantitative methodology designed to use the indicator rating of the WPL in order to classify plant communities as wetland, or nonwetland (upland). In general, they tested two techniques, each one based on replicated sampling. One technique is termed the weighted average (WA) method. In this method, each species in a sample is rated according to abundance or importance. The abundance value for a given species is multiplied by its WPL indicator rating (1 through 5). The sum of these products for all species in a sampling unit is divided by the sum of the abundance values for all species in the unit to yield the weighted average. The mean of the weighted averages for replicated units in a plant community is then used to determine if the community is wetland (WA<3) or nonwetland (WA>3). A simpler method tested was the index average method (termed unweighted average, UA, in this report). In this methodology, the mean of the WPL indicator ratings of all species occurring in the sampling unit is used, and the overall mean of replicated units in the community is treated the same as for the WA method (i.e., <3 is wetland and >3 is upland).

Wentworth and Johnson (1986) found that both WA and UA methods yielded similar results and that most plant communities could be correctly classified. However, certain communities fell into what the authors term a "gray area" between 2.5 and 3.5. If a site falls into this "gray area", then vegetation data was believed to be inadequate to classify a site and soil or hydrological data must be used.

The National Technical Committee for Hydric Soils (NTCHS) has developed criteria for the designation of hydric soils (Appendix A). These criteria have been used by the United States Soil Conservation Service (SCS) to develop lists of hydric soils for each state. The hydric soils list for South Dakota (HSL) contains 70 soil series (SCS, 1985b). Most of these soils, however, have not been critically evaluated in the field. Field studies of these soils need to be conducted in order to determine if these soils support wetland plant communities in their natural, or undisturbed, condition. This is an extremely important consideration, because a great many temporary and seasonal wetland-dominated basins in South Dakota are tilled and cropped during times when ponding does not occur. Thus, natural vegetation does not occur in them, and the soil series designation is the only means by which to definitely designate them as wetland. Stewart and Kantrud (1973) estimated that in 1967 in North Dakota's pothole region, 25% of the wetland area and 48% of the wetland basins were "undifferentiated tillage ponds" that were either centrally dominated by temporary or seasonally flooded water regimes.

The objectives of this study were to: (1) review the literature on glacialted prairie wetland soils, vegetation, and relationships between them, (2) compute the community indicator ratings, based on the WPL indicator values, for six soils listed on the HSL, for one hydric soil not listed, and for three upland soils in order to test the premise that hydric soils support wetland plant communities and nonhydric soils support upland plant communities, and (3) test the relationship between the six soils on the HSL and the WPL.

LITERATURE REVIEW

CLASSIFICATION OF GLACIATED PRAIRIE WETLANDS

In both numbers and area, closed or semi-closed basin (depressional) wetlands comprise the bulk of the wetlands in the region (Stewart and Kantrud, 1973; Ruwaldt et al., 1979). Classification systems for these depressional wetlands have been developed by Stewart and Kantrud (1971) in North Dakota and Millar (1976) in Saskatchewan. The system of Stewart and Kantrud (1971) has been cited extensively. The major classification criteria (Class) is based on a physiognomic concept; however, each Class is comprised of zones that are defined by the duration of inundation. Indicator species are used to define the zones and each zone can be modified by salinity and disturbance.

The classification system in nationwide use by most Federal agencies is that of Cowardin et al. (1979), and is the system used in this report. This system is based on an area rather than a physiognomic concept. Differences between the Cowardin system and Stewart and Kantrud system are detailed in Cowardin (1982). With the exception of some deep lacustrine habitats, depressional prairie wetlands are all in the palustrine system of Cowardin, the most common classes being emergent or aquatic bed. The most informative and useful level for differentiating these wetlands by the Cowardin system is water-regime. The zones of the Stewart and Kantrud system compare directly with water-regime modifiers of the Cowardin system (Cowardin et al., 1979: Table 5; Cowardin, 1982: Fig. 1).

A temporary wetland of Stewart and Kantrud has a central wet meadow zone that typically grades into a low prairie zone toward the upland. The low prairie zone is a nonwetland by the Cowardin system (Cowardin et al., 1979), but the wet meadow zone would be classified as having a temporary water-regime by Cowardin. A seasonal wetland of Stewart and Kantrud has a central zone of shallow marsh typically surrounded by wet meadow. The shallow marsh zone equates to the seasonal water-regime of Cowardin. A semipermanent wetland of Stewart and Kantrud has a central zone of deep marsh typically surrounded by zones of shallow marsh, and further landward, zones of wet meadow. Deep marsh equates to the semipermanent regime of Cowardin. Thus, a Stewart and Kantrud temporary Class contains one kind of Cowardin-system wetland, the seasonal Class contains two kinds of Cowardin-system wetlands, and the semipermanent Class contains three kinds of Cowardin-system wetlands. The semantics of the systems can be confusing (Cowardin, 1982) and most of the recent literature uses the Stewart and Kantrud system. However, where data from other studies are discussed in this report or where convenience dictates use of the physiognomic concept, the seasonal and semipermanent Classes of Stewart and Kantrud will be

referred to as potholes or basins "dominated by seasonal wetland" and "dominated by semipermanent wetland" respectively. Use of the terms "temporary", "seasonal" and "semipermanent" will pertain to a discrete type of palustrine (either emergent or aquatic bed) wetland. When necessary to distinguish between any temporary wetland and the Stewart and Kantrud temporary Class, the term "individual temporary" will be used for the latter.

Some of the older literature cited in this review used no classification system, or used a system developed by the investigators. In these instances, the Cowardin system will be used to describe their data where possible. The species lists of Stewart and Kantrud will be used to make these descriptions. For example, Dix and Smeins (1967) used drainage regime categories to differentiate plant communities. These authors provide species lists that, when compared to the indicator lists of Stewart and Kantrud (1971), can be "translated" into wetland categories of Cowardin et al. (1979). Although some local differences of species occurrences exist across the prairie pothole region, most of the dominant wetland species are ubiquitous, making the "translations" fairly easy to make.

PRAIRIE WETLAND SOILS

Knowledge of wetland soils is required to obtain a better understanding of prairie potholes. Cowardin et al. (1979) stated, "Soil is one of the most important physical components of wetlands." Soils play a major role in the determination of the vegetation and organisms present in and around a wetland area. According to the United States Soil Conservation Service, areas are not considered to have soil if the surface is permanently covered by deep enough water that only floating plants are present (Soil Conservation Service, 1975). Most wetlands have soil based on the above definition. Because of the difficulty in obtaining wetland soil pedons and of the lack of interest by soil scientists in classifying wetland soils, there is little information available on wetland soils (Bigler and Richardson, 1984).

The variation in wetland soils explain many characteristics associated with prairie potholes. Soils are useful in determining landscape position (Malo, 1974), hydrological characteristics (Miller et al., 1985), drainage class (Simonson and Boersma, 1972), and water table fluctuations (Daniels et al., 1971). Such inferences can be made because waterlogging sets in motion biological and chemical processes that cause changes in the physical and chemical properties of the soil (Patrick and Mahapatra, 1968).

Bigler and Richardson (1984) studied four semipermanent wetland-dominated potholes in North Dakota and concluded that: (1) particle size classes ranged from fine-loamy in the peripheral temporary and seasonal wetland to fine in the central semipermanent wetland; (2) thickness of the horizons with Munsell color values (Munsell Color, 1975) <3.5 (moist) increased from temporary to semipermanent wetland; (3) soil color became progressively more gleyed from temporary to semipermanent wetland and was similar throughout the semipermanent wetland; (4) channel

ferrans were more common in the temporary and seasonal wetland than in the semipermanent wetland; and (5) no B horizons were present.

Bigler and Richardson (1984) felt that the coarser textures at the edge of the pothole occur during deposition and result from a slope decrease from the surrounding area. Textural changes are a direct result of sedimentary processes and not pedologic activity (Malo, 1974; Bigler and Richardson, 1984). Malo (1974) concluded that at lower landscape positions, particle sorting results in a more uniform material. Wetland soils, as a whole, tend to belong in the fine particle-size family (Bigler and Richardson, 1984).

The slow decomposition of organic matter in submerged soil is the reason for the increased thickness of the zone with color values <3.5 (moist) in the open water zone (Bigler and Richardson, 1984). Decomposition is slow because it is almost entirely the work of anaerobic bacteria, which are less diverse than aerobic microorganisms (Ponnamperuma, 1984). Gambrell and Patrick (1978) reported that anaerobic conditions reduce the rate of decomposition of native organic matter in soil to half that of aerobic conditions.

The dry, crushed Munsell values are a well defined function of the degree of saturation in soils (Simonson and Boersma, 1972). The values are lighter in color (more gleyed) when soils have been saturated for a longer period of time. Daniels et al. (1971) found that gleyed colors develop at soil depths saturated more than 50 percent of the time. Horizons that have predominantly gray colors (chroma ≤ 2) in the matrix or argillans are saturated much of the year. Horizons that have a dominant chroma of 3 in the matrix, mottles, or argillans are frequently saturated (Franzmeier et al., 1983) Soil color is related to redox potential and variation of the watertable level (Bigler and Richardson, 1984). Redox potential falls rapidly after flooding, reaches a minimum within a few days, rises to a maximum, and then decreases asymptotically with time (Ponnamperuma, 1984). Mohanty and Patnaik (1975) found that the decline in redox potential was greater in soils high in organic matter and iron. The presence of organic matter and a temperature of 35 C favor decreases in redox potential (Ponnamperuma, 1984).

Mottles are found in soils that possess alternating, reducing, and oxidizing conditions. The relative depth at which waterlogging occurs in the profile has a strong influence on the formation of mottles (Simonson and Boersma, 1972). Richardson and Hole (1979) found no mottle development in well drained sites where unsaturated conditions dominate; a considerable number of mottles at somewhat poorly drained sites where the dry-wet cycle is common; and a few mottles at very poorly drained sites where stagnant water conditions exist. The presence and nature of mottles are a key morphological feature for soil drainage conditions and high water tables (Pickering and Veneman, 1984). However, mottles cannot always be used for identification of hydric conditions (Bouma, 1973; 1983; Moormann and van de Wetering, 1984) because:

(1) Mottles may be relicts of an historical hydrologic regime and thus not the present conditions.

(2) Saturation of soils may not always result in reducing conditions that produce mottles. This can happen when discharging groundwater contains high levels of dissolved oxygen, soil temperatures are below 5 C, or when energy (organic matter) sources for microbial mediated reduction are lacking.

(3) Their occurrence does not identify the length time of saturation.

(4) Mottles may be masked by organic matter stains.

(5) Mottles may not form due to the color of the original sediment.

Channel ferrans may be more common in the emergent wetland phase as compared to the open water phase because: (1) the soils are more oxidized, allowing oxidation of iron and/or (2) plant species add oxygen to the soil roots, creating channel ferrans (Bigler and Richardson, 1984). The oxygen produced by photosynthesis in the aerial or floating foliage is transported down the lacunar system and normal intercellular spaces into the root system. Because of oxygen diffusion from the roots of marsh plants, the rhizosphere is oxidized (Armstrong, 1978). The thickness of the oxidized rhizosphere is determined by the ratio of oxygen supply from the atmosphere to oxygen consumption of the soil (Patrick and Reddy, 1978).

The loss of iron appears to diminish the probability of channel ferrans in the open water zone (Bigler and Richardson, 1984). Gotoh and Patrick (1973) found that a combination of low redox potential and low pH had a marked effect on the increasing solubility of at least part of the solid-phase, iron compounds. Richardson and Hole (1979) found that the average amount of iron in a profile increases with increased moisture content, reaching a maximum at poorly drained sites and then decreasing at very poorly drained sites. The movement of iron is a twofold translocation; (1) interhorizon translocation from the surface to the lower solum which was found from well drained sites to very poorly drained sites; and (2) intrahorizon movement in which iron moves into the peds, which occured only in the somewhat poorly drained and poorly drained sites. This latter phenomenon is caused by alternating periods of oxidation and reduction which causes the iron equilibria to pass through stages of increased solubility. Then, as water moves into a dry ped, it carries the solubilized iron with it.

There was no B horizon present in semipermanent wetlands because (1) drying infrequently occurs and (2) the presence of calcium carbonate in the soil can prevent dispersion and subsequent translocation of clays or humus (Bigler and Richardson, 1984; Buol et al., 1980). In potholes dominated by seasonal and temporary wetland, argillic horizons are common because of the many wetting and drying periods. Malo (1974), Miller et al. (1985), and

Arndt and Richardson (1986) found clay enriched illuvial horizons in seasonal wetland-dominated potholes.

Groundwater flow plays a major role in wetland soil formation. Wetlands can be groundwater recharge, discharge, or flow-through types, depending on landscape position and/or groundwater movement. Wetlands in topographically high (on a local basis) positions are usually temporary or seasonal wetland-dominated and contain fresh, snowmelt-derived water which recharges the groundwater. Wetlands lower in the local landscape receive a significant portion of their water from groundwater discharge and tend to be larger, more permanent, and more saline (Arndt and Richardson, 1986). Flow-through wetlands are generally located between recharge and discharge wetlands. These wetlands both recharge and discharge groundwater at various points within the basin. Discharge and flow-through wetlands are typically dominated by semipermanent or intermittently exposed water regimes. Because the recharge and discharge of the groundwater system is influenced by fluctuations in the watertable, groundwater flow may temporarily change in potholes (Lissey, 1971; Winter and Carr, 1980).

Arndt and Richardson (1986) studied recharge, discharge, and flow-through wetlands in North Dakota. The temporary and seasonal wetland of a recharge pothole had pedons free of carbonates and were non-saline. The profiles were well developed with illuvial clay in the B horizon and had high organic matter contents at the surface that decreased gradually with depth. This is a good indication that seasonal wetting and drying is taking place in recharge wetlands. The water surface on recharge wetlands represents the top of a groundwater mound, which progressively flattens over the summer and results in clay translocation. Generally non-carbonate, non-saline, and leached soils occur in recharge areas (Miller et al., 1985).

The profiles in a discharge wetland are poorly developed, calcareous, saline, and reflect a stable, high, saline watertable. Miller et al. (1985) also found carbonate and saline soils in discharge areas. The temporary wetland soil profile is less saline than the semipermanent wetland soil profile because fresher groundwater is discharging through the peripheral temporary wetland. The organic matter content is high at the surface but decreases rapidly with depth in semipermanent wetland-dominated potholes.

The flow-through wetland was larger, more permanent, and more saline than the recharge wetland. The temporary wetland and seasonal wetland soil profiles were calcareous throughout and had no evidence of clay translocation. The organic matter content was highest at the surface but decreased rapidly with depth. The lack of frequent drying and wetting cycles in the semipermanent wetland and the lack of downward water movement in most parts of the basin prevented profile development (Bigler and Richardson, 1984; Richardson and Bigler, 1984).

The calcareous soils found in the temporary and seasonal wetland of discharge and flow-through potholes are known as Calciaquolls. Calciaquolls have a calcic horizon that contains a large equivalent of

calcium carbonates. Knuteson et al. (1986) listed four conditions that favor the formation of Calciaquolls: (1) the capillary fringe from a watertable reaching the root zone; (2) evapotranspiration exceeds precipitation during summer months; (3) bicarbonate and sulfate anions dominate the shallow ground water; (4) freezing temperature draws soil water to the surface in the winter. Miller et al. (1985) also noticed upward movement of carbonates by capillary rise. Malo (1975) examined the movement of water from the watertable to the colder zone at the bottom of the frost zone at lower landscape positions. Cerling (1984) states that as soil water freezes, salts accumulate in the solution (i.e. "freezes-out") leading to calcite formation in northern Great Plains soils. Arndt and Richardson (1986) noted that freezing-out occurred in wetlands leading to increased concentrations of dissolved solids in the water beneath the ice.

Wetland soils are physically and chemically different than other soils because they are waterlogged. Due to the limited supply of oxygen available through diffusion, oxygen concentration in the soil is reduced to zero by the respiration of microorganisms within a few hours of waterlogging (Mohanty and Dash, 1982). The physical and chemical properties of these soils and the duration of submergence has a large influence on the quality of the soil as a medium for plant growth (Ponnamperuma, 1984).

In summary, highly developed B horizons are found in recharge wetlands. This is due to the seasonal wetting and drying and downward water movement taking place in recharge wetlands. Discharge and flow-through wetlands have no clay translocation and are calcareous throughout. The lack of frequent wetting and drying prevents profile development.

PRAIRIE WETLAND VEGETATION

In a study of the native prairie vegetation of Nelson County, North Dakota, Dix and Smeins (1967) identified 268 species and found an additional 25 taxa that could not be identified. Of these species, 120 occurred in at least one stand with a frequency of at least 50%. When the average frequency values of these 120 species were calculated for each category of each edaphic factor studied, it became apparent that their qualitative assessment of drainage regime gave the best correlation with species distribution. Upon further analysis, only 48 species were found to be useful as indicators of drainage regime. They also investigated some soil characteristics in relation to species distribution. Characteristics measured were texture, water-retention capacity, pH, carbonate presence, electrical conductivity of soil extracts, sulfate, chloride, and soil moisture. However, while a few of the soil characteristics demonstrated weak correlations, none were as useful as drainage regime in determining vegetation distribution. The wettest regimes used in their study are "wetland" according to the Cowardin et al. system (1979) and an important point brought out by their data is that there are clearly fewer species of plants found in wetlands than on uplands.

In another study of native prairie in northwest Minnesota, Smeins and Olsen (1970) found that both species composition and standing crop followed a moisture regime gradient, more so than other measured soil factors. Soil factors considered were water retention capacity, texture, and organic matter (loss on ignition). The two wettest communities described by these authors equate to temporary wetland according to their species list. Similar to the findings of Dix and Smeins (1967), there were noticeably fewer species present in the wetland than in the uplands.

The early works on classifying prairie potholes by vegetation have been briefly summarized in Stewart and Kantrud (1971, 1972) and Millar (1976), who concluded that salinity and water permanence are factors that apparently influence the vegetation. The classification systems of Stewart and Kantrud (1971) and Millar (1976) both recognize and use the influence of water permanence and salinity on vegetation in their schemes. Each system provides species lists of indicator plants for various water regimes and salinity categories. Additionally, the effect of disturbance, either natural or man-induced is recognized in these systems. The effects of prolonged drought or prolonged high water levels are also considered by both systems. Under extreme hydrological conditions, wetlands that normally exhibit species characteristics of a certain water regime may develop species characteristics of another regime.

The detailed findings of the investigations used to develop the classification system of Stewart and Kantrud are reported in Stewart and Kantrud (1972); the salinity ranges observed for each species of indicator plant for each water-regime (wetland zone) are listed. The authors maintained that the plant species are probably a better indicator of average salinity conditions than are point-in-time measurements of specific conductance because conductivity can vary substantially through a season due to effects of dilution from recent precipitation or concentration due to evapotranspiration. In addition, species are listed for water regimes in undisturbed and disturbed stands. The disturbance situations described are (1) natural drawdown--soil exposing events due to drawdown on uncultivated soils, (2) cropland drawdown--soil exposed after drawdown that had been tilled prior to reflooding, and (3) cropland tillage--tilled wetlands that are left fallow and remain dry. Ubiquitous, weedy, annual and biennial, forbs and grasses are the primary kinds of species, as well as some weedy perennials that colonize in these situations. Soil exposing events caused by natural drawdown are more frequent in semipermanent wetlands where open water areas become exposed. However, extreme high water in seasonal wetlands can result in death of emergent species and conversion to open water, after which drawdown exposes the bare soil. Some drawdown species will temporarily persist after reflooding. Effects of other disturbances on species composition, such as grazing, mowing, burning, and past cultivation, are also discussed.

The changes that occurred in 71 stands of seasonal wetland vegetation over a 10-year period of generally improving moisture regime in Saskatchewan have been described by Millar (1973). The occurrence of greater-than-normal water depths at the start of a growing season can cause decreases in density of several plant species. Two or more years of

continuous flooding, however, were required to convert an emergent, seasonal wetland to open water. Grazing and cultivation changed species composition, but mowing and burning did not. Several species, all of which were grasses, indicated disturbance.

In a study of 64 wetland plant stands in Saskatchewan that included the major water-regimes, Walker and Coupland (1968) found that the dominant species were principally responding to water-regime, but also to salinity gradients. They included two soil properties, percent organic matter (loss on ignition technique) and texture, in their investigation, but very little association between these properties and species distribution was found. Although unquantified, disturbance was noted as having an impact on species distribution. Walker and Coupland (1970) found that water regime, salinity, and disturbance are the main environmental gradients affecting species distribution in 246 wetland plant stands. Soil attributes of organic matter, texture, and water-holding capacity did not show definite relationships with the vegetation.

In an attempt to overcome the influence of disturbance and salinity extremes, Walker and Wehrhahn (1971) selected 34 stands of temporary and seasonal wetlands that were relatively undisturbed and had low salinities. They used principal component analysis to evaluate the effects of 26 environmental factors, including water-regime, and various chemical and physical attributes of the water and soils. In spite of the fact that these stands were selected based on their undisturbed condition, disturbance was the most important factor influencing the variation in vegetation. The available nutrients, water-regime, and salinity were also important.

Natural disturbance in the form of drawdowns due to the unstable climatic conditions of the prairie has been deemed a necessary part of the "marsh cycle" of semipermanent wetland- dominated prairie potholes (Weller and Spatcher, 1965; Weller, 1981). A typical cycle begins with a wetland at drawdown when mud-flat, annual species and emergent-hydrophyte seeds germinate. Increasing water levels over the ensuing years kills the mud-flat annuals and allows full emergent development. After several years of high water, emergent vegetation gives way, either due to muskrat (Ondatra zibethicus) herbivory or unfavorable soil conditions, and the marsh becomes open water. At this point the wetland is unsuitable habitat for most breeding wildlife species. However, migratory birds may still utilize it during migration. Drought causes declining water levels until another drawdown develops. During drawdown accumulated organic matter decomposes, nutrients are released into the system, and plant species germinate. The cyclic nature of the climatic regime of the prairies controls this cycle, and aberrations in climatic patterns can cause resultant aberrations in the wetland cycle.

The natural disturbance caused by fluctuating water levels was studied on a glacial wetland in Iowa by van der Valk and Davis (1976a). Vegetation measurements were taken in 1973, a more-or-less normal year, and in 1975 when water levels were higher than normal. The intervening year (1974) was one of extremely low water levels due to drought. Overall species

composition along the two transects changed little from 1973 to 1975; however, shifts in position of several species occurred, as well as the appearance of species not present in 1973 and the disappearance of some species that were present in 1973. Carex spp., Potamogeton spp., and Sagittaria spp. all moved closer to shore in 1975 due to the increased water levels. However, such species as Glyceria grandis, Alisma subcordatum, and Sparganium eurycarpum moved deeper into the wetland. This latter phenomenon was due to germination of these species on the exposed substrate during the 1974 drawdown and their subsequent persistence upon reflooding in 1975.

In a 5-year study of a large semipermanent wetland in the pothole region in Iowa, van der Valk and Davis (1980) found evidence to support their hypothesis that periodic drawdown enables several emergent species to coexist. They found that Typha glauca, Scirpus fluviatilis, and Sparganium eurycarpum, were adversely affected by drought, while it caused a temporary reversal of decline in vigor of Scirpus validus that had begun prior to the drought.

Studies on several large basins dominated by semipermanent wetlands in Iowa have shown that species composition of the seed banks from various zones of vegetation within the same basin are much more similar to each other than are seed banks from other basins, even when seed banks from the same zones of different basins were compared (van der Valk and Davis, 1976b). Thus it seems that seed dispersal mechanisms operate more-or-less uniformly over a given basin. This would mean that seeds of species from all portions of the basin, plus those from highly mobile upland weeds, could germinate anywhere in the basin following a drawdown. However, thick accumulations of plant litter may inhibit germination after drawdown (van der Valk, 1986). The role of seed banks in Weller's marsh cycle (Weller and Spatcher, 1965; Weller, 1981) has been further researched and discussed in van der Valk and Davis (1978). Based on successional theory, van der Valk (1981, 1982) has developed a conceptual model, that uses life history aspects of adult and seed bank species that can be used to predict species changes in a wetland due to disturbance.

From this brief review, it is apparent that wetland species respond to water regime, disturbance, and salinity. Water regime and disturbance are interrelated. While disturbance can be man induced, natural water level changes also disturb wetland vegetation to varying degrees. Plant communities will respond to disturbance according to the life histories of the contemporary and seed bank species.

PRAIRIE WETLAND PLANT AND SOIL CORRELATION STUDIES

Studies by Dix and Smeins (1967), Smiens and Olsen (1970), and Walker and Wehrhahn (1971) included some soil variables in their analyses of vegetation. However, either due to the strong overriding influences of water-regime and disturbance, or inappropriately chosen soil variables, few strong associations with the vegetation were noted. We are aware of only one study that has comprehensively investigated soil characteristics in

relation to wetland vegetation in the Dakotas (various aspects of the study were reported in Fulton et al., 1979 and Bigler and Richardson, 1984). Soil information and vegetation measurements were collected from the temporary, seasonal, and semipermanent wetlands that occurred in four basins.

Fulton et al. (1979) reported that the vegetation zonation (i.e., wetland type) correlated with calcium carbonate content and pH ($p<0.05$, statistical methods not given), and marginally correlated with percent organic carbon. Water level changes were correlated with soil type, organic carbon, pH, sodium level, and sodium adsorption ratio ($p<0.01$). They also found that vegetation density, biomass, and species presence correlated with water level changes ($p<0.01$). Vegetation density also correlated with zone, calcium carbonate content, sodium level, and sodium absorption ratio ($p<0.01$). They reported that vegetation density was a better indicator of soil properties than was the type of vegetation.

Bigler and Richardson (1984) reported that Cumulic Haplaquolls and Fluvaquentic Haplaquolls were found in the central semipermanent wetlands; however, one subsite in the semipermanent wetland of one basin had a Typic Fluvaquent. Typic Haplaquolls, Cumulic Haplaquolls, and Fluvaquentic Haplaquolls were found in the peripheral, seasonal wetlands. Typic Haplaquolls, Typic Fluvaquents, and Fluvaquentic Haplaquolls were found in the peripheral, temporary wetlands. Thus, at this gross level of classification, water regime did not appear to have a consistent relationship with soils. Overall however, all of the wetland soils were of the fine family and none had B horizons. The lack of B horizons indicated a lack of downward water movement and/or a lack of frequent periodic drying. This would imply that all four basins were groundwater discharge or flow-through wetlands. Several soil properties were related to water-regime (see previous section on Wetland Soils). Soil series were not given for the temporary and seasonal wetlands, but the semipermanent wetlands had soils corresponding to the Southam series. Other than this study, there have been no attempts to investigate wetland plant community types with soil series designations. The following report on our own research will be the first of its kind in South Dakota.

STUDY AREA

Sites were selected with primary consideration given to areas in undisturbed natural vegetation and to areas within prevalent soil associations of glacial till in eastern South Dakota. Areas considered were all FWS Waterfowl Production Areas (WPA), or S.D. Department of Game, Fish and Parks Game Production Areas (GPA).

The Severson WPA, located approximately one mile west of Lake Cochrane (NW1/4, Sec. 5, T114N, R47W) in Deuel County was selected as a site. This site contained over 25 depressional wetlands dominated by several water-regimes and was predominantly in native, uncultivated, mixed grass prairie and was typical of Cary-age, end moraine of the eastern Prairie Coteau. Deuel County is located in the eastern northcentral portion of South Dakota (Figure 1). The site is managed periodically with early season grazing every few years to control invading, cool-season, tame-grass species. It was last grazed in 1984. An additional factor influencing the selection of this site was the availability of data collected by a previous study of the South Dakota Cooperative Fish and Wildlife Research Unit.

We visited most of the WPAs and GPAs in Beadle County, South Dakota, and could not find a suitable site equal to the suitablity of the Deuel County site. We therefore subjectively selected two, similar, seasonal, wetland-dominated depressions, one located on the Andresen WPA (SE1/4, Sec. 7, T110N, R64W) and the other on the Brecken Slough GPA (NE1/4, Sec. 13, T110N, R65W) in western Beadle County. In 1971 the upland immediately surrounding the pothole on the Andresen site was planted to dense nesting cover, a mixture of Agropyron intermedium, Medicago sativa, and Melilotus officinalis. However, the site had since been overtaken by smooth brome grass (Bromus inermis), a condition prevalent on presently uncultivated areas throughout eastern South Dakota. The uplands surrounding the pothole on the Brecken Slough site were presently cultivated (small grain and corn). The Beadle County sites were located in the drift prairie area of the James River Lowland (Figure 1).

SOILS OF THE DEUEL COUNTY SITE

The study area in Deuel County was located in the Barnes-Buse-Parnell association. This soil association is found on glacial end moraines. Slopes can be nearly level to hilly; they are steeper along the sides of entrenched drainage ways and in end moraines. There are many closed potholes throughout this association. About 30% Barnes soils, 15% Buse soils, 15% Parnell soils, and 40% minor soils make up this association (Figure 2).

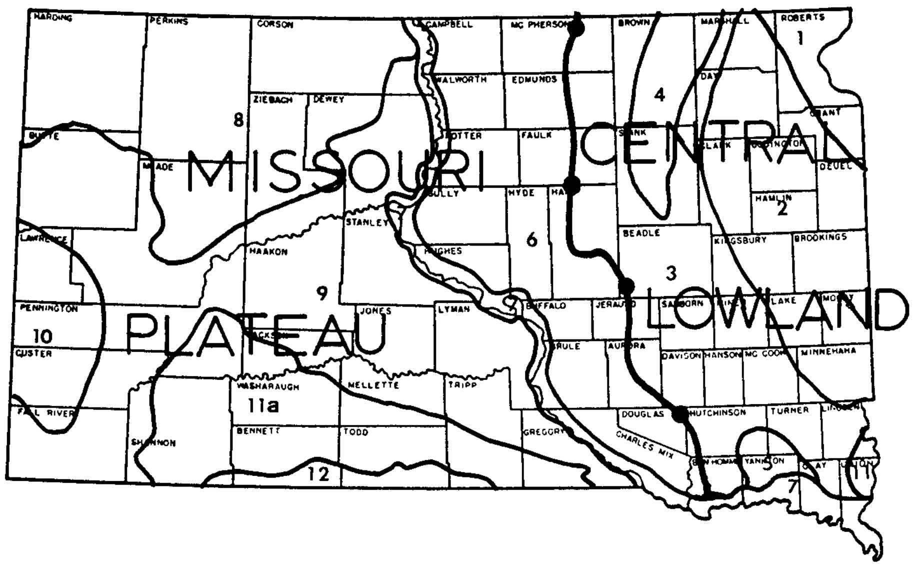

Figure 1. Physiographic regions of South Dakota (from Westin and Malo, 1978).

1. Minnesota River--
   Red River Lowland
2. Prairie Coteau
3. James River Lowland
4. Lake Dakota Plain
5. James River Highland
6. Missouri Coteau
7. Missouri River Trench
8. Northern Plateaus
9. Pierre Hills
10. Black Hills
11. Newton Hills
11a. Southern Plateaus
12. Sand Hills

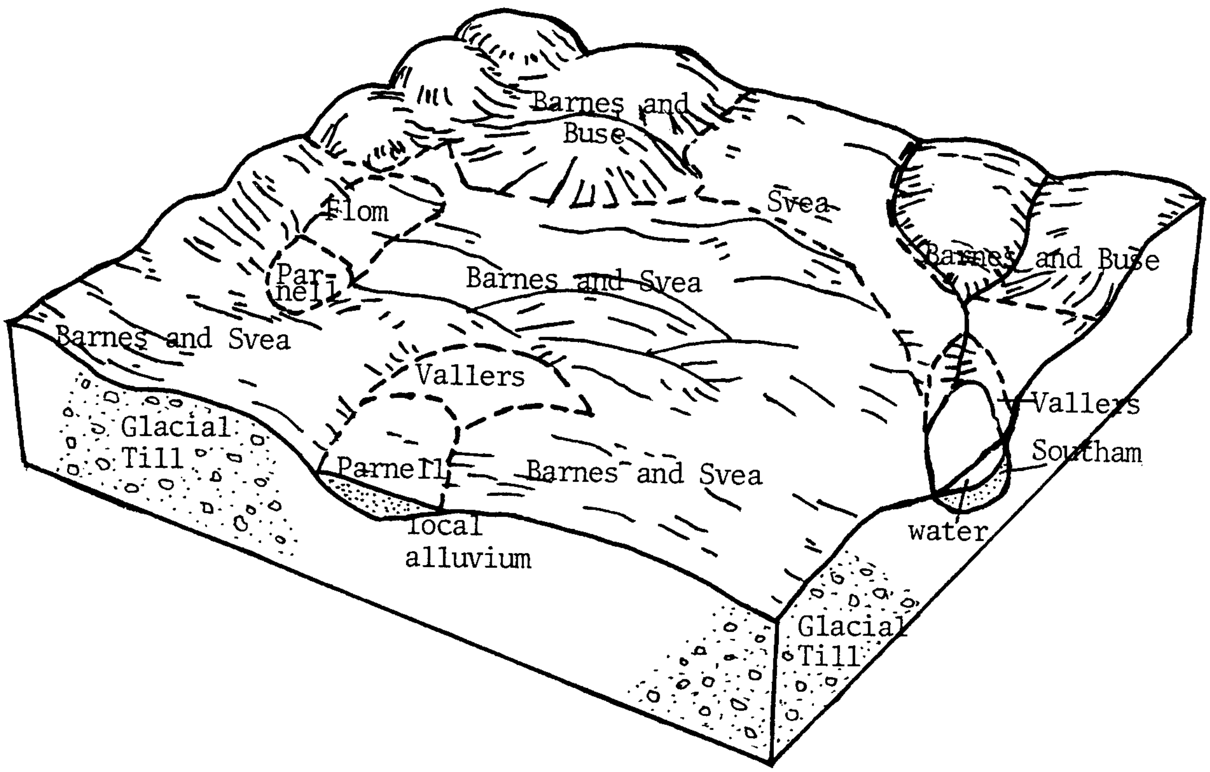

Figure 2. General pattern of soils and underlying material in the Barnes-Buse-Parnell association which represents the study area soils in Deuel County.

Barnes soils are well drained on level to hilly uplands. Slopes are convex and linear and generally less than 15%. The Barnes soils have a solum thickness from 10 to 23 inches. The mollic epipedon is typically 7 to 12 inches thick but can range up to 16 inches. The surface layer is a dark gray loam. The subsoil is a brownish loam and the underlying material is a light yellowish brown, calcareous loam.

Buse soils are well drained and occur on ridges and steep side slopes. Slopes are slightly to strongly convex and generally <40%. Buse soils have a thinner solum then the Barnes soils and have free calcium carbonate in the upper part of the solum. The shallow surface layer is of dark grayish loam material. The subsoil is a light brownish gray, calcareous loam. The underlying material is a light yellowish brown, calcareous loam.

Parnell soils are very poorly drained and are located in depressions (temporary and seasonal wetland-dominated basins). Slopes are nearly level (<1%) to slightly concave. Solum thickness can range up to 70 inches. The A horizon is very dark gray, silty clay loam. The B horizon is dark gray, firm silty clay. Underlying material is grayish brown, silty clay loam.

Minor soils in this association are Svea, Flom, Vallers, and Southam. Svea soils are moderately well drained and located on nearly level and slightly concave positions. The slope gradient is commonly <3% but can range up to 9%. The Flom soils have plane or slightly concave slopes with a gradient <3%. The poorly drained Flom soils are located in swales and on rims of potholes (temporary wetlands). Vallers soils have slightly concave to slightly convex slopes with a gradient from 0 to 3%. The poorly drained Vallers soils have a calcic horizon and are located on rims of potholes (seasonal and semipermanent wetland-dominated basins). Southam soils are very poorly drained with slopes <1%. Southam soils are located in depressions (semipermanent, wetland-dominated basins).

About 75% of this association is used for crops and as tame pastures and hayland. The main crops are corn, small grain, and alfalfa. The rest of this soil association is in native grass and is used as pasture and for hay. If the soils are used for crops, the main concerns of management are controlling erosion on the steep slopes, conserving moisture, and maintaining tilth and fertility. Terracing and contouring are not feasible in most areas because of the short, irregular slopes and because of the many potholes located in this soil association. This soil association has good potential for the development of habitat for openland and rangeland wildlife.

SOILS OF THE BEADLE COUNTY SITES

The Beadle County study area was located on the Hand-Bonilla soil association. This association is on a glacial plain underlain by stratified loamy glacial drift. The plain consists of gentle swells that rise 10 to 30 feet above the swales and numerous small depressions or potholes that dot the landscape. Slopes are mostly undulating, but some

are nearly level to gently rolling. Steeper slopes are on sides of some of the ridges and along creeks and drainageways. The drainage pattern is poorly defined in the nearly level areas where shallow swales terminate in the potholes.

This soil association is about 30% Hand soils, 20% Bonilla soils, and 50% minor soils (Figure 3). The well drained Hand soils are on rises and swells. Hand soils are nearly level to rolling, slopes are short and irregular with a gradient range from 0 to 15%. The thickness of the mollic epipedon ranges from 8 to 20 inches.

Bonilla soils are in drainageways, swales, and footslopes. The moderately well drained Bonilla soils have typical slopes of <2%, but range from 0 to 6%. The thickness of the mollic epipedon is >20 inches. The Hand and Bonilla soils both have dark grayish brown surface layers. The subsoil is friable loam and clay loam. The underlying material is light yellowish brown, calcareous clay loam.

The minor soils are the Betts and Ethan soils on the sides and tops of ridges and knolls; the Delmont and Enet soil in areas that are underlain by sand and gravel; the Dudley and Stickney soils in some of the swales and on flats; the poorly drained Durrstein and Egas soils on bottom land along drainageways; and the poorly drained Hoven and Tetonka and very poorly drained Worthing soils in closed depressions. Hoven soils have slopes <2% and are located on the outer rims of potholes. Hoven soils have a natric horizon. Tetonka soils also have slopes <2% and are located on the rims of potholes below the Hoven soil. Tetonka soils have an albic and an argillic horizon but no natric horizon. Worthing soils are located in the bottom of potholes below the Tetonka soil. The plane or concave bottom of the pothole where Worthing soils are present have a slope of <1%.

About 70% of this association is used for crops and tame pastures or hayland. Corn, small grain, and alfalfa are the main crops. Some areas of the steeper soils on the sides of ridges and drainageways and on the poorly drained soils in potholes are in grass and are used for pasture. Controlling erosion and conserving moisture are the main concerns if the major soils are cropped. This association has good potential for crops, tame pasture and hayland, range, and openland and rangeland wildlife habitat.

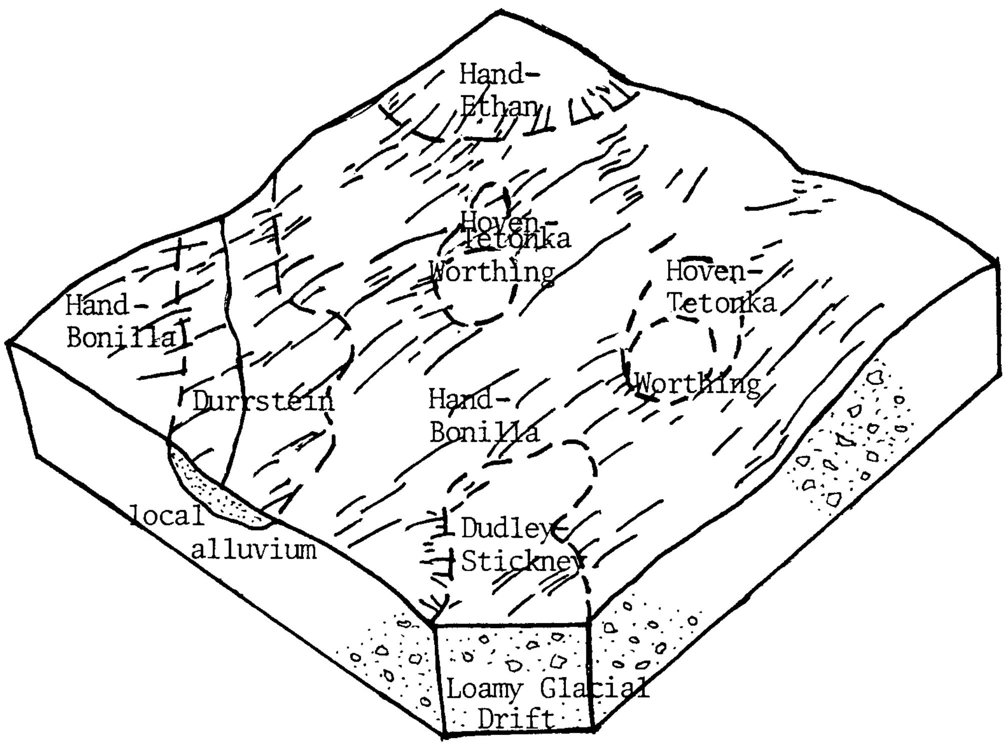

Figure 3. General pattern of soils and underlying material in the Hand-Bonilla association which represents the study area soils in Beadle County.

METHODS

POLYPEDON DELINEATION

Published soil surveys could not be used to delineate soil series boundaries because the mapping units used by the SCS include soils of several series. Therefore, prior to actual selection of wetland and adjacent upland soils for study, preliminary traverses of the study sites were made using a hand soil probe to locate potential soils. After determining the size of a few soil polypedons, it became apparent that many polypedons on the Deuel County site were too small for the inclusion of more than one replication (rep) of vegetation measurements on a soil series, as required by the sampling scheme devised at a meeting of contractors (May 1986, Fort Collins, Colorado) for this and related studies. For example, the largest Flom polypedon mapped was approximately 23 m long by 5 m wide. Four polypedons each of the following hydric soils were located at the Deuel County site: Flom, Parnell, Southam, and Vallers. Four polypedons each of two upland soils, Barnes and Svea, were also located. It is important to note that the Southam soil series, while listed on the North Dakota HSL, was not listed on the 1985 South Dakota HSL. The Southam series, however, has been officially recognized as existing in South Dakota since completion of this study and is now listed on the South Dakota HSL.

Hoven, Tetonka, and Worthing soils (all on the HSL) were found in both wetland basins used at the Beadle County sites. Only one polypedon each of Worthing and Hoven could be located at each of these sites; however, they were large enough to accommodate two vegetation replications. Two Tetonka polypedons were located at each site (four total). Because the Brecken Slough GPA upland was entirely tilled and cropped, the Hand soils occurring there could not be used for this study. Consequently, we studied four polypedons of Hand soil located within the watershed of the pothole on the Andresen WPA.

SOIL COLLECTION AND ANALYSIS

Once the upper and lower boundry of each soil polypedon was determined at all study sites, the soil was sampled in the center of the upslope/downslope boundaries. Soil samples were collected using a hydraulic soil coring machine, except where water saturated the soil or was ponded on the soil surface. In the latter instances, a hand-held post hole digger was used. The morphology of each core was described according to the New Soil Survey Manual (SCS, 1981). The cores were subsampled on the

basis of morphology, and air dried for subsequent chemical and physical analysis.

The soil testing was done by the South Dakota State Soil Testing Laboratory. The soil tests completed were readily oxidizable organic matter (Schulte, 1980), pH (Peech, 1965), water soluble nitrates (Carson,1980a), available potassium (Carson, 1980b), and available phosphorus (Knudsen, 1980).

Cation exchange capacity (Chapman, 1965), calcium carbonate equivalent (Bundy and Bremner, 1972), sodium adsorption ratio (SCS, 1972), and electrical conductivity (Rhoades, 1982) have also been measured on soil samples.

VEGETATION METHODS

Herbaceous Stratum (ground cover)

Plot size was 0.5 m x 1.0 m. Ten plots were selected from within each of four polypedons (reps) of each soil series, except for the Hoven and Worthing soils where two reps of 10 plots were selected from within each of two polypedons. A transect was placed through the center of the longest axis of the polypedons and measured with a tape. The number of 1.0 m intervals along a transect was used as the pool from which 10 intervals were randomly selected using a random numbers table. Half of the 10 plots in each rep were randomly assigned to the right side of the transect, and the other five plots to the left of the transect. Except for Parnell, Southam, Tetonka, and Worthing soils, which had slopes of approximately zero, this meant that half of all plots within a rep were taken on the upslope side of a polypedon, and half on the downslope side. Exceptions to this were on one rep of Barnes in which the transect was arranged perpendicular to the slope and on two other Barnes, one Svea, and one Vallers rep where data existed from a previous study (D.E. Hubbard, 1985, unpublished data) on the site.

Plots were placed perpendicular to the transect with the closest edge one meter from the transect. However, in situations where the polypedon was too narrow to permit this, the plot placement was adjusted to accommodate the soil boundary.

In addition to the above mentioned reps, data for one Parnell rep were also obtained from the previous, 1985 study, in which data were collected in the same manner as for this study, except that 0.35 m x 0.70 m plots were used.

Abundance data for each species occurring in each plot was recorded using canopy coverage classes 0 through 6 as described by Daubenmire (1968).

Short Shrub Stratum

If short shrubs (woody dicots >0.5 m and <1.3 m tall) occurred within a rep, then a 2.0 m x 2.0 m plot size was used. Five plots were randomly selected, independent of herbaceous plots but in a similar fashion, using 2.0 m intervals as the pool from which to select the subsample. Abundance of shrubs for each species was determined by counting all individual plants (clumps) emerging from the ground.

Other Strata

No tall shrubs (woody dicots >1.3 m tall and <7.5 cm dbh) or trees (woody dicots >7.5 cm dbh) occurred at any of the sites.

INDICATOR RATINGS AND NOMENCLATURE

All species present were assigned a wetland indicator rating as listed in the NPL (Reed, 1986). The regional indicator rating was used (Region 4). However, in those cases where species were not rated for this region, the national rating was used. Numerical ratings of 1 for obligate hydrophytes, 2 for facultative wetland plants, 3 for facultative plants, 4 for facultative upland plants, and 5 for obligate upland plants were assigned. A listing of scientific names, codes, and NWI ratings (numerical) is presented in Appendix B. Several species were listed by both the numerical rating and as drawdown species. In these cases, the first indicator rating was used and not the drawdown rating.

Plant species identification was based on Van Bruggen (1976) and Great Plains Flora Association (1986). Dr. Gary E. Larson, Associate Professor of Biology at South Dakota State University, provided species verification. When nomenclatural differences between these sources and the National List of Scientific Plant Names (NLSPN) (U.S. Department of Agriculture, 1982) occurred, the nomenclature of the latter was used. Species names were coded using the codes provided by the NLSPN.

NUMERICAL ANALYSIS OF COMMUNITIES

Both weighted average (WA) and unweighted average (UA) methods (Wentworth and Johnson, 1986) were used to express the community values. A WA for each plot was calculated using the formula:

$$WA_j = \left(\sum_{i=1}^{p} I_{ij} E_i\right) / \left(\sum_{i=1}^{p} I_{ij}\right)$$

where:

- WA = weighted average for plot "j"
- I = canopy coverage estimated for species "i" in plot "j"
- E = NWI indicator rating for species "i"
- p = the number of species occurring in plot "j"

A UA for each plot is merely the average of the NWI indicator ratings for the species in each plot. In addition, we present WA and UA values using our suggested changes in ten species indicator ratings (Appendix F) and excluding facultative species.

RESULTS AND DISCUSSION

DEUEL COUNTY SOILS

The well drained Barnes soil and the moderately well drained Svea soils were the two upland soils studied in Deuel County. The Barnes and the Svea soils were nonhydric (Tables 1 and 2). The Barnes soil was found on the higher convex slopes and the Svea soil was located on the lower concave slopes. Because the Svea soil was lower in the landscape, it had better development in the B horizon due to increased water movement and is nine inches thicker than the Barnes solum (Table 3). The high organic matter content of these two soils (Table 4) was the result of the study area supporting native vegetation. The Barnes and the Svea were the dominate upland soils around the study potholes.

The Flom, Vallers, Parnell, and Southam soils all belong to an aquic suborder and are poorly or very poorly drained (Tables 1 and 2). Aquic soils have three main horizons: a partially oxidized A horizon in which organic matter accumulates, a zone in which oxidizing and reducing conditions alternate, and a zone of permanent reduction. In the second zone, iron and manganese are alternately reduced and oxidized. During oxidation, iron and manganese oxides are deposited as mottles (Ponnamperuma, 1984). Vepraskas and Wilding (1983) stated that the most common method for determining aquic moisture regime in soils is the height of the watertable during the growing season. Veneman et al. (1976) found that mottles with a chroma of two or less did not occur when the soil was only saturated for one day. However, after several days of waterlogged conditions they found that iron was removed from the interior of the peds resulting in low chromas in the remaining soil material. This type of mottling was dominated by chromas of two inside the peds. Thus it is possible to determine the height of the watertable during a growing season if this event lasts for a significant period of time. This is very useful because the height of the watertable must be determined to accurately identify hydric soils (Appendix A).

However, problems can occur because saturated conditions may not always cause low chroma mottles. Soils that are saturated with well oxidized water may not allow for the development of gleyed soil colors when iron is maintained in a ferric form. (Buol et al., 1980). The soil temperature must also be above biological zero (5 C) at the time the soil is saturated in order for soil microbial respiration to remove or deplete oxygen (Soil Management Support Services, 1985). Cold water also holds more oxygen than warm water. Because snowmelt runoff and spring precipitation are the two largest water sources for a pothole, the cold,

Table 1. General characteristics of the soils studied as summerized from SCS established series description sheets (Form-5) for each soil.

Soil series	Parent material	Drainage class	Effective depth	Percent slope	Surface runoff	Solum permeability	C Horizon permeability	Landform
Barnes	glacial till	well drained	deep	0-25	medium or rapid	moderate	moderately slow	level to hilly till plain
Svea	glacial till	moderately well-drained	deep	0-9	slow	moderate	moderately slow	concave position on till plain
Flom	local inwash over till	poorly drained	deep	0-3	slow	moderately slow	moderately slow	level to hilly glacial moraine
Vallers	local inwash over till	poorly drained	deep	0-3	slow	moderately slow	moderately slow	depression on glacial moraine
Parnell	local alluvium	very poorly drained	deep	<1	v slow or ponded	slow	slow	depression on glacial moraine
Southam	local alluvium	very poorly drained	deep	<1	ponded	slow	slow	depression on glacial moraine
Hand	stratified glacial drift	well drained	deep	0-15	medium	moderate	moderate	glacial outwash plain
Hoven	local alluvium	poorly drained	deep	0-2	ponded	very slow	very slow	upland depression on till plain
Tetonka	local alluvium	poorly drained	deep	0-2	ponded	very slow	very slow	upland depression on till plain
Worthing	local alluvium	very poorly drained	deep	<1	ponded	slow	slow	upland depression on till plain

Table 2. Classification of soils from field studies and test results.*

Soil series	Drainage class	Classification	Hydric vs nonhydric	Surface permeability (in/hr)	High water depth (ft)	table months	Hydric ** criteria
Barnes	well drained	Fine-loamy, mixed Udic Haploboroll	non hydric	<6.0	>6.0	----	----
Svea	moderately well-drained	Fine-loamy, mixed Pachic Udic Haploboroll	non hydric	<6.0	4.0-6.0	Apr-Jun	----
Flom	poorly drained	Fine-loamy, mixed frigid Typic Haplaquoll	hydric	<6.0	1.0-3.0	Nov-Jun	2B2
Vallers	poorly drained	Fine-loamy, frigid, Typic Calciaquoll	hydric	<6.0	1.0-2.5	Nov-Jun	2B2
Parnell	poorly drained	Fine, montmorillonitic, frigid Typic Argiaquoll	hydric	<6.0	+2.0-2.0	Jan-Dec	2B2/3
Southam	very poorly drained	Fine, montmorillonitic, frigid Cumulic Haplaquoll	hydric	<6.0	+5.0-1.0	Jan-Dec	3
Hand	well drained	Fine-loamy, mixed Typic Haplustoll	non hydric	<6.0	>6.0	----	----
Hoven	poorly drained	Fine, montmorillonitic, mesic Typic Natraquoll	hydric	<6.0	+1.0-1.5	Mar-Jul	2B2/3
Tetonka	poorly drained	Fine, montmorillontic, mesic Argiaquic Argialboll	hydric	<6.0	+1.0-1.0	Jan-Dec	2B2/3
Worthing	very poorly drained	Fine, montmorillonitic, mesic Typic Argiaquoll	hydric	<6.0	+1.0-1.0	Jan-Dec	2B2/3

* Classification of soils from Soils of South Dakota (Westin and Malo, 1978)
** see Appendix A

Table 3. Field description of soils studied.

Soil series	Horizon	Depth (in)	Boundary* distinctness	Matrix color	Texture*	Structure*	Mottles*	Color of mottles	Moist* consistence	CaCO3 equiv.
Barnes	A	0-6	clear	10YR2/1	l	m-g	----	----	fr	0
	Bw	6-14	abrupt	10YR3/1	l	m-sbk	----	----	fr	1.0
	Bk	14-26	clear	2.5Y5/4	l	m-sbk	fdf	5YR4/6	fr	20.0
	C	26-61	----	2.5Y4/4	l	sl-m	mpc	5Y6/1, 10YR4/6	fi	22.6
Svea	A	0-8	clear	10YR2/1	l	m-g	----	----	fr	0
	Bw	8-15	clear	10YR3/1	l	m-sbk	----	----	fr	5.4
	Bk	15-35	clear	2.5Y4/3	l	m-sbk	fff	5Y6/1, 7.5YR5/6	fr	16.2
	C	35-61	----	2.5Y4/4	l	sl-m	mdc	5Y6/1, 7.5YR4/6	fi	20.2
Flom	A1	0-9	clear	N2/0	sicl	m-g	----	----	fr	0
	A2	9-19	clear	10YR2/1	sicl	m-sbk	----	----	fr	0
	Bw/Bg	19-30	clear	10YR2/2	cl	m-sbk	----	----	fr	0
	Bg/Bkg	30-44	gradual	2.5Y4/2	cl	w-sbk	fdm	2.5Y5/4	fr	2.1
	Cg	44-72	----	5Y5/1	cl	sl-m	mpc	2.5Y5/6, 7.5YR4/6	fr	14.6
Vallers	A1	0-7	clear	N2/0	sicl	m-g	----	----	fr	7.3
	A2	7-13	clear	10YR2/1	sicl	m-sbk	----	----	fr	9.9
	Bk	13-22	clear	10YR3/1	sicl	m-sbk	----	----	fr	12.2
	Bkg	22-42	clear	2.5Y4/2	sil	w-sbk	fdf	7.5YR4/6	fr	21.3
	Cg	42-62	----	5Y6/1	sil	sl-m	mpc	7.5YR5/6, 10YR5/8	fr	21.7
Parnell	A1	0-9	clear	N2/0	sil	m-g	----	----	fr	0
	A2	9-19	clear	10YR2/1	sil	w-sbk	----	----	fr	0
	Bt1	19-31	clear	10YR2/2	sic	s-sbk	----	----	fi	0
	Bt2	31-46	clear	10YR3/1	sic	m-sbk	----	----	fi	0
	Btg	46-70	----	5Y5/2	sicl	m-sbk	mpc	7.5YR4/6, 5Y6/4	fi	6.0
Southam	Ag1	0-11	gradual	N2/0	sicl	sl-m	----	----	fr	0
	Ag2	11-25	gradual	N2/0	sic	sl-m	----	----	fi	0
	Ag3	25-38	gradual	5Y2.5/1	sic	sl-m	fff	7.5YR3/4	vfi	1.0
	Cg	38-50	----	5Y2.5/1	sic	sl-m	cdm	7.5YR4/6, 10YR4/4	vfi	2.6
Hand	A	0-7	abrupt	10YR2/1	l	m-g	----	----	fr	0
	Bw	7-15	clear	10YR3/2	l	m-sbk	----	----	fr	5.6
	Bk	15-31	clear	2.5Y4/4	l	w-sbk	----	----	fr	24.5
	C	31-61	----	2.5Y5/4	l	sl-m	cdm	5Y4/1, 7.5YR4/6	fr	16.6
Hoven	A	0-3	abrupt	10YR2/1	sil	m-g	----	----	fr	0
	E	3-7	abrupt	10YR3/1	sil	w-pl	----	----	vfr	0
	Bt/Bt1	7-22	clear	10YR3/1	sic	s-cpr	----	----	fi	0
	Btk	22-37	clear	2.5Y3/2	sic	m-sbk	----	----	fi	6.1
	Btk2/Bk	37-50	clear	2.5Y5/2	sicl	w-sbk	fdf	7.5YR5/6	fr	10.4
	C	50-65	----	5Y5/1	sicl	sl-m	mpc	10YR4/6	fr	20.3
Tetonka	A	0-8	abrupt	10YR2/1	sil	m-g	----	----	fr	0
	E	8-14	abrupt	10YR4/1	sil	m-pl	----	----	vfr	0
	Bt/Bt2	14-38	clear	10YR3/1	sic	m-pr	----	----	fi	0
	Btk/Bk	38-61	clear	5Y5/2	sicl	w-sbk	cdm	10YR4/6	fi	13.6
	C	61-81	----	5Y5/2	sicl	sl-m	mpc	7.5YR5/6, 10YR5/8	fi	13.3
Worthing	A1/A2	0-12	clear	10YR2/1	sil	m-g	----	----	fr	0
	Btg1	12-26	clear	10YR2/1	sic	m-pr	----	----	fi	0
	Btg2	26-42	clear	10YR3/2	sic	s-pr	----	----	fi	0
	Btg3	42-51	clear	5Y4/2	sic	m-sbk	ffm	5Y5/3	fi	0
	Bg/Bkg	51-67	clear	5Y4/2	sicl	w-sbk	mpc	N5/0, 10YR4/6	fr	6.4
	C	67-79	----	5Y5/2	sicl	sl-m	mpc	2.5Y5/6, 7.5YR4/4	fr	5.5

* See Appendix B for explanation of abbreviations

Table 4. Mean value of laboratory test results from soils studied.

Soil series	Horizon	Lower depth (in)	Thick-ness (in)	NO3 (ppm)	P (Bray) (ppm)	P (Olsen) (ppm)	K (ppm)	OM (%)	pH	CEC meq/100g	extractable bases Ca meq/l	Mg meq/l	K meq/l	Na meq/l	SAR meq/l	EC mmhos/cm
Barnes	A	6	5-7	1.5	3	3	250	5.7	6.9	26.60	17.58	3.91	0.89	0.08	0.45	779
	Bw	14	7-10	1.0	1	2	150	3.1	7.3	20.10	18.34	2.98	0.50	0.05	0.51	661
	Bk	26	7-21	1.0	0	1	80	1.4	8.1	14.32	36.88	3.60	0.24	0.06	0.65	556
	C	61	24-41	1.0	0	1	75	0.2	8.3	12.50	35.83	7.19	0.21	0.06	1.41	236
Svea	A	8	6-11	2.0	2	3	140	5.3	7.3	30.71	28.64	4.73	0.59	0.08	0.63	1005
	Bw	15	6-8	1.5	1	2	90	3.5	7.9	18.89	40.32	4.49	0.30	0.12	0.65	769
	Bk	35	15-24	1.5	0	2	75	1.6	8.1	17.20	42.82	5.98	0.22	0.12	0.94	456
	C	61	23-32	1.0	1	1	90	0.1	8.1	13.31	42.06	6.88	0.29	0.12	1.42	354
Flom	A1	9	8-9	1.0	3	3	145	4.6	6.3	41.10	12.77	3.88	0.54	0.50	0.51	530
	A2	19	6-11	1.0	1	2	120	2.8	6.7	35.90	12.29	3.75	0.43	0.41	0.58	445
	Bw/Bg	30	9-12	1.0	1	1	120	1.4	7.3	23.20	13.69	4.62	0.46	0.41	0.67	483
	Bwg/Bkg	44	10-16	2.0	1	1	120	0.7	7.7	23.00	22.03	5.08	0.45	0.31	0.62	564
	Cg	72	26-31	1.0	1	1	110	0.1	8.0	17.30	12.02	1.85	0.37	0.35	0.66	435
Vallers	A1	7	6-7	2.0	3	4	100	6.1	7.9	38.44	40.00	8.43	0.38	0.23	1.53	1536
	A2	13	5-7	2.0	1	3	80	4.4	8.1	32.70	38.96	9.76	0.27	0.28	1.23	1136
	Bk	22	4-16	2.0	1	2	85	2.7	8.1	25.96	44.63	9.45	0.27	0.33	1.53	966
	Bkg	42	16-23	1.0	1	1	105	0.9	8.1	20.82	37.21	7.54	0.32	0.35	1.63	613
	Cg	62	16-27	1.0	1	1	100	0.1	8.1	14.41	36.51	6.27	0.37	0.24	1.57	584
Parnell	A1	9	8-9	3.0	15	10	220	4.2	6.2	34.92	20.81	6.63	0.78	0.37	0.73	588
	A2	19	8-13	1.0	10	6	180	1.9	6.2	29.12	17.65	5.55	0.62	0.47	0.86	441
	Bt1	31	6-16	1.0	16	10	185	1.0	6.3	31.07	17.28	6.63	0.61	0.47	0.85	444
	Bt2	46	12-18	1.0	26	19	215	0.5	6.5	26.99	15.43	6.12	0.70	0.51	0.82	419
	Btg	70	17-28	1.0	20	19	160	0.2	6.9	25.90	15.81	5.60	0.59	0.41	0.65	720
Southam	Ag1	11	10-13	2.0	6	5	125	7.4	7.0	39.51	8.59	4.42	0.50	0.54	0.53	1969
	Ag2	25	13-16	1.0	6	4	140	3.7	7.3	35.60	13.21	6.48	0.46	0.51	0.56	1500
	Ag3	38	11-17	1.0	5	3	170	1.3	7.4	24.12	8.42	5.39	0.57	0.45	0.60	1158
	Cg	50	10-15	1.0	4	5	200	0.7	7.4	25.42	13.77	6.06	0.70	0.44	0.64	869
Hand	A	7	6-8	3.0	5	4	685	3.4	6.7	19.65	15.91	4.16	1.30	0.27	0.71	3025
	Bw	15	6-13	2.0	2	2	220	1.6	7.3	19.16	31.10	6.11	1.90	0.29	0.78	993
	Bk	31	13-17	1.5	1	2	220	0.6	8.1	13.18	52.86	10.06	3.13	0.34	1.46	1023
	C	61	24-35	1.5	1	2	370	0.1	8.4	13.36	53.28	10.94	3.40	0.65	4.78	2569
Hoven	A/E	7	5-10	3.5	35	23	745	2.6	6.4	22.71	10.70	5.19	1.61	0.84	5.48	873
	Bt1/Bt2	22	12-17	2.0	12	7	650	0.6	7.6	22.70	11.89	9.77	3.63	1.40	13.81	6156
	Btk	37	9-19	2.0	12	4	670	0.2	8.3	19.91	12.10	14.88	4.74	2.28	20.81	3444
	Btk2/Bk	50	9-20	3.0	16	7	550	0.1	8.6	19.70	26.16	11.97	3.72	0.92	11.34	1668
	C	65	11-20	2.0	6	6	380	0.1	8.6	16.62	36.83	9.70	3.02	0.96	11.33	1309
Tetonka	A	8	6-9	2.0	41	26	865	2.9	6.2	22.43	10.51	4.12	1.30	0.33	1.15	690
	E	14	4-8	1.0	21	14	300	0.5	6.5	8.45	4.53	2.41	0.75	0.75	1.46	478
	Bt/Bt2	38	16-38	1.5	17	10	835	0.5	7.0	24.66	11.53	10.20	3.17	0.40	1.70	669
	Btk/Bk	61	13-38	2.0	8	9	460	0.2	7.9	17.48	31.47	8.38	2.61	0.50	3.63	1205
	C	81	15-25	2.0	4	5	290	0.1	8.0	18.22	34.20	6.85	2.13	0.56	2.74	920
Worthing	A/A2	12	7-17	5.0	84	58	920	2.7	5.9	25.10	8.74	3.36	1.05	0.44	1.08	554
	Btg1	26	9-19	2.0	82	69	840	0.9	6.1	23.68	8.18	3.75	1.17	0.52	1.24	386
	Btg2	42	11-20	1.0	70	48	715	0.5	6.4	21.22	13.06	5.85	1.82	0.67	1.19	360
	Btg3	51	10-15	1.0	60	30	425	0.2	6.6	21.38	10.34	4.78	1.49	0.47	1.31	492
	Bg/Bkg	67	10-32	2.0	25	16	300	0.2	7.3	15.63	17.98	3.77	1.17	0.46	0.96	926
	C	79	10-20	1.0	18	14	275	0.1	7.7	14.62	12.99	3.39	1.06	0.48	1.25	650

well-oxygenated water conditions listed above are very possible around prairie potholes in the spring.

The soil temperature is rarely above 5 C immediately after snowmelt, when the watertable mound below a temporary or seasonal wetland-dominated basin is typically at its highest in the prairie pothole region. Before the temperature can reach 5 C the watertable could drop considerably, thus the depth at which the soil is indicating saturated conditions could be false. The Deuel County site is located within the area of frigid temperature regimes, meaning the growing season does not start until May (according to NTCHS, 1986). Hubbard and Linder (1986) measured the volume of 213 small wetlands in northwestern South Dakota in April of 1982, immediately after the vernal thaw. Water depths were measured then because maximum depth usually occurs in that month. Because of this situation, soils could be classified nonhydric, even though the soil could be ponded or near saturation before the growing season.

These problems could be solved if a frequency factor was incorporated into the hydric soil criteria in addition to the watertable depth. An inundation or high watertable frequency of 50% could be used for a long-term average; similar to the frequency used by the NTCHS (1986) for flooding. For example if a soil had a watertable at less than 1.5 feet from the surface for a significant period during the growing season in five of ten years, the soil could be considered hydric. This frequency factor would also alleviate the problem of low watertable in seasonal and temporary dominated-wetlands due to drought conditions. Because drought conditions are common in the Dakotas, it is typical for some temporary and seasonal wetland-dominated potholes to be dry or even have a watertable at depths greater than 1.5 feet from the surface for several consecutive years. Hence, an inundation frequency factor of 50% should also be associated with hydric soil criteria 3 (Appendix A), which deals with soils that are ponded.

The Flom soil was located between the moderately well drained Svea soil and the poorly drained Parnell soil. The poorly drained Flom soil formed a rim around the temporary wetland-dominated potholes. The Flom soil apparently received surface runoff from upslope uplands, because calcium carbonates were leached deeper in the profile and the solum of the Flom soil was considerably thicker than the Svea soil immediately upslope (Table 3). The data in Table 2 indicate that the Flom soil is hydric (criteria 2B2). Gleyed colors were found within 19 to 30 inches from the soil surface, which indicates reducing conditions caused by a high watertable. Daniels et al. (1971) found that gleyed colors develop at profile depths that are saturated more than 50% of the time. Pickering and Veneman (1984) and Richardson and Hole (1979) found the lowest matrix chroma colors in poorly drained soils where the reducing environments were strongest. Low chroma values were found in the Flom soil (Table 3). Munsell hues (Munsell Color, 1975) of 2.5Y and 5Y, in conjunction with low chromas and mottles in subsoil horizons, have long been recognized as a reliable indicator of waterlogging in soils with reducing conditions (Soil

Survey Staff, 1951). These conditions were present in the Flom soil (Table 3) due to the high watertable present in the spring from surface runoff.

The Vallers soil was located on the rims of seasonal and semipermanent dominated-wetland potholes. A Svea soil was located upslope from the the Vallers soil and a Parnell soil was located downslope from it in two seasonal wetland-dominated potholes, while a Southam soil was located downslope from the Vallers in a semipermanent wetland. The poorly drained Vallers soil is a hydric soil (criteria 2B2, Table 2). The Vallers soil is a Calciaquoll because it contains a calcic horizon (Bk) and was calcareous throughout the profile (Table 3). Capillary rise from a shallow watertable and evapotranspiration exceeding precipitation in the summer months are the main causes for the formation of Calciaquolls (Knuteson et al., 1986). The high pH values in the Vallers soil were due to the high amounts of calcium carbonates present in the profile. Arndt and Richardson (1986) found calcareous soils around groundwater discharge and flow-through semipermanent wetland-dominated potholes. Vallers zones were larger around semipermanent than seasonal wetland-dominated potholes in Deuel County. The Vallers soil demonstrated no evidence of clay translocation. Bigler and Richardson (1984) found that profile development was limited in calcareous soils due to lack of wetting and drying associated with large watertable fluctuations.

Parnell soil was located in the temporary and seasonal wetland-dominated potholes. Parnell soil was surrounded by Flom soil in the temporary wetland-dominated potholes and by Vallers soil in the seasonal wetland-dominated potholes. The poorly drained Parnell soil is hydric (criteria 2B2 and/or 3, Table 2). There had apparently been a significant amount of leaching in Parnell soil due to many wetting and drying cycles, because the profile had well developed illuvial Bt horizons, was leached of calcium carbonates (Table 3), and also had a slightly acidic pH value due to the leaching of salts (Table 4). The Parnell soil had no mottles or gleyed matrix colors in the top 45 inches of the soil profile (Table 3). This is due to the masking effect caused by the humus (decomposing organic matter). The amount of snowmelt runoff and the watertable depth at the beginning of the winter are factors that determine whether the Parnell soil will be ponded and for what duration.

Southam soil was located in semipermanent wetland-dominated potholes. Southam soil is surrounded by Vallers soil. The very poorly drained Southam soil is hydric (criteria 3, Table 2). Southam soil was ponded throughout the growing season. Several dry years would be needed before the Southam soil would be exposed. Due to continuous reducing conditions, there is limited soil development, as evidenced by the lack of a B horizon and the massive structure throughout the profile (Table 3). Bigler and Richardson (1984) studied four semipermanent wetland-dominated potholes in North Dakota and found Southam soil in each. They concluded that the vegetation in a semipermanent wetland can be used to predict properties of the underlying soil.

BEADLE COUNTY SOILS

Hand soil was the upland soil studied in Beadle County. The well-drained Hand soil is nonhydric (Table 2). Hand soil has limited soil development because of surface runoff (Table 3).

The Hoven, Tetonka, and Worthing soils all belong to an aquic suborder or an aquic great group and are poorly or very poorly drained (Tables 1 and 2). Hoven soil is located on the rim of the seasonal wetland- dominated potholes upslope from Tetonka soil. The poorly drained Hoven soil is hydric (criteria 2B2 and/or 3, Table 2). Hoven soil is a Natraquoll, which has a well developed argillic horizon and a large quantity of sodium in the profile. The high pH values in the lower (2nd and 3rd) soil horizons indicate that sodium was still present in the profile (Table 4). The strong columnar structure present in the top of the argillic horizon is also indicative of a natric horizon (Table 3). Hoven soil had Munsell hues of 2.5Y and 5Y, low chroma colors, and mottles in the subsoil, all indicating a waterlogged condition. Hoven soil can be ponded in the early spring due to its low landscape condition.

Tetonka soil is located between the poorly drained Hoven soil and the very poorly drained Worthing soil. The Tetonka is a hydric soil (criteria 2B2 and/or 3, Table 2). Wetting and drying cycles have caused much leaching in Tetonka soil, as evidenced by the great depths to calcium carbonates and the formation of albic and argillic horizons (Table 3). Tetonka soil is usually ponded after snowmelt runoff and heavy rains, a condition that causes gleyed colors and mottles in the subsoil horizons. Miller et al. (1985) found in their study of upland depressions with both an albic and argillic horizon that three potholes had water ponded on the soil surface while a fourth pothole had a watertable within 1.5 feet of the soil surface. The soil in these potholes, which were very similar to the Tetonka soil, would have a hydric criteria number of 2B2 and/or 3.

Worthing soil is located in the lowest portion of the depressions studied. This very poorly drained soil is found downslope from Tetonka soil. Worthing soil is a hydric soil (criteria 2B2 and/or 3, Table 2). Worthing soil is similiar to the Parnell soil in that much water moves through the profile. Because of leaching, soluble salts were removed, pH values were low (Table 4), clays were translocated to form an argillic horizon, and calcium carbonates were found at great depths (Table 3). Worthing soil is typically ponded in the spring and early summer.

PLANT COMMUNITIES

Herbaceous Stratum

A total of 160 species, five genera (unidentifiable to species level), and one taxanomic group, (algae) were identified on study plots (Appendix C). All taxa are listed in descending order of frequency of occurrence in all 400 plots in Appendix D. The algae, *Riccia fluitans*, and *Ricciocarpus natans*, are all non-vascular hydrophytes and are not listed in the WPL or

in the NLSPN. However, as they are obligate hydrophytes, we have included them in the analysis. The code names ALGAE, RIFLX, and RINAX were used in the data set for these non-vascular taxa. These last two codes follow NLSPN conventions but with an X appended in case of the existence of an identical name in the database. The NLSPN genus codes for unidentified taxa are used.

Typha glauca (a hybrid of T. angustifolia and T. latifolia) is perhaps the most common form of Typha in the state and is not listed in the South Dakota WPL. But it is listed in the National WPL. Eleocharis obtusa is listed nationally, though not locally. Both T. glauca and E. obtusa, should be included on the state list. Ammannia robusta is a new species (Great Plains Flora Association, 1986) that does not occur on either the WPL or NLSPN, but it is apparently an obligate hydrophyte. Its code (AMROX) has been assigned using the NLSPN conventions but with an X appended to designate its tentative status. Typographical errors were found in the code for Symphoricarpos occidentalis in the NLSPN, and in the code for Sagittaria cuneata in the state WPL. The correct codes of SYOC and SACU are used in this report.

Shrub Stratum

Most of the woody dicots occurring at the sites were short enough to be included in the herbaceous stratum. However, shrubs over 0.5 m tall occurred on three polypedons: one Vallers and two Svea. By chance, no shrubs occurred in the randomly selected plots on one Svea replication (rep), and Symphoricarpos occidentalis and Amorpha canescens occurred in one plot each on the other Svea transect. One Vallers transect containing shrubs had high densities of Symphoricarpos occidentalis in most of the plots. Due to the virtual absence of shrubs on the study site, they were not included in the analyses.

Effect of Unknown Species on Replication Community Values

To evaluate the effect of the unidentifiable species on the weighted average (WA) of the soil reps in which they occurred, WAs were calculated for each rep using the maximum possible and minimum possible ratings for species within their respective genera on the state WPL. In addition, replicate WAs were calculated after deleting those taxa from the data (Table 5). The effect of this exercise was slight for most reps and in no case did it cause a rep WA to change from wetland to upland or vice versa. However, using the maximum value in Tetonka rep 4 caused the WA to move up into the "gray area" Based on these data, we deleted the unknown species from the data set for all further calculations.

Community Values of Soil Series

The mean WAs of all 40 plots for each soil series are listed in Table 6, as well as the relationship of the series to the state HSL (SCS, 1985b) and hydric soil criteria (NTCHS, 1986). Also listed in Table 8 are the ranges in water regimes that were indicated by the species composition of the vegetation in the individual plots. This classification by water

Table 5. Comparison of weighted averages of soil replications (n = 10 for each rep.) containing unidentifiable species using the maximum possible NWI rating, minimum possible NWI rating, and deleting the species from the data set.

Soil/replication		Weighted averages		
		Maximum	Minimum	Deleted
Hydric soils:				
Flom	Rep 4	3.86	3.85	3.85
Hoven	Rep 4	1.83	1.77	1.78
Parnell	Rep 4	1.03	1.00	1.00
Tetonka	Rep 2	2.20	2.17	2.17
	Rep 3	2.46	2.35	2.39
	Rep 4	2.61	2.27	2.39
Vallers	Rep 1	3.31	3.30	3.29
	Rep 4	2.59	2.58	2.58
Worthing	Rep 2	1.10	1.07	1.07
	Rep 3	1.36	1.13	1.14
	Rep 4	1.47	1.24	1.26
Upland Soils:				
Barnes	Rep 2	4.41	4.40	4.40
	Rep 3	4.32	4.30	4.31
Svea	Rep 1	4.19	4.18	4.18
	Rep 3	4.12	4.12	4.12
	Rep 4	4.15	4.14	4.14

Table 6. General summary of results.

Soil Series	Soils		Plants	
	On List?[a]	Morphological Verification	Weighted Average[b]	Water Regime[c]
Southam	No	Hydric	1.00	SP
Worthing	Yes	Hydric	1.23	S
Parnell	Yes	Hydric	1.48	T/S
Tetonka	Yes	Hydric	2.46	S
Vallers	Yes	Hydric	2.78	non/T
Hoven	Yes	Hydric	2.96	non/T/S
Flom	Yes	Hydric	3.85	non
Svea	No	Upland	4.18	non
Barnes	No	Upland	4.30	non
Hand	No	Upland	4.58	non

[a] South Dakota Hydric Soils List (SCS, 1985).
[b] n = 40.
[c] Water regimes according to Cowardin et al. (1979):
T = temporarily flooded, S = seasonally flooded,
SP = semipermanently flooded, non = non-wetland.

regime essentially constitutes an independent "test" of the methodology as it is based on the species lists provided by Stewart and Kantrud (1971) (see "Classification of Glaciated Prairie Wetlands" section). The mean WAs for all four reps of all hydric soils studied, except Flom, had values under 3.0 (Table 6). However, if values are rounded to the nearest tenth, then the Hoven soil WA would be equal to 3.0. If rounded to the nearest whole number, both Hoven and Vallers would equal 3. The range of water regimes found on the plots within each soil series indicated that the use of a 3.0 value for distinguishing between wetland and upland may have merit. The Flom (hydric) soil, having a WA of 3.85, did not qualify as a wetland by either the WA method or by the assessment of water regimes (Table 6). However, the use of a 3.0 cutoff value cannot be recommended, based on these figures, as individual reps of Hoven and Vallers soils were above this value. Descriptive statistics for the WA method for all upland soils, by rep, are listed in Table 7. Descriptive statistics for the hydric soils are listed in Table 8. Coded species lists for each soil type are given in Appendicies E-1 through E-10.

Coefficients of variation (CV) for all of the upland soils (Barnes, Hand, Svea) (Table 7) are all very small, both within reps and over all reps, indicating a high degree of uniformity of the plot WAs. The overall means for these soils indicate that they are all correctly classified as upland soils based on the vegetation; all upland soil means are over 4.0. Species that occurred on these soils are listed in Appendicies E-1 through E-3.

The Southam soil reps and overall soil means all have very small CVs (Table 8). All reps of this wetland soil have WA means of 1.00 and thus it is correctly classified as a hydric soil. The vegetation plant communities found on this soil are characteristic of semipermanent wetlands (Appendix E-4).

The rep means and overall soil means for Parnell and Worthing (Table 8) are strongly indicative of wetland, but CV values show that the WAs are more variable than the upland soils. The plant communities of the Parnell reps were indicative of temporary and seasonal wetland (Appendix E-5), and the Worthing soils supported stands that were indicative of seasonal wetland (Appendix E-6).

The Tetonka reps 2, 3, and 4 had WA means that were clearly wetland (WA <2.5) (Table 8). However, rep 1 was in the "gray area". This rep's value elevated the soil mean to almost the "gray area" but still correctly classifies the soil as hydric. The rep CV values for this soil were generally higher than for the previously mentioned soils. Species on these soils were generally indicative of seasonal wetland in drawdown condition (Appendix E-7).

The Flom, Hoven, and Vallers soils, while all hydric based on the NTCHS criteria (Appendix A), appear to be "problem soils" based on vegetation WAs (Table 8). All Flom reps had mean WAs that are strongly upland in character (Table 8). The small CVs for Flom show little variability in plot values. Three of the Vallers reps had mean WAs in the

Table 7. Means, standard errors, and coefficients of variation for plot weighted averages for each replication and all replications of each upland soil.

Rep	n	Mean	Std. Error	C.V.
			Barnes Soil	
1	10	4.26	0.03	1.90
2	10	4.40	0.03	2.21
3	10	4.31	0.03	1.95
4	10	4.23	0.03	2.07
All	40	4.30	0.02	2.49
			Hand Soil	
1	10	4.75	0.06	3.84
2	10	4.36	0.05	3.47
3	10	4.56	0.06	4.51
4	10	4.67	0.06	4.18
All	40	4.58	0.04	5.06
			Svea Soil	
1	10	4.18	0.05	3.92
2	10	4.26	0.02	1.76
3	10	4.12	0.06	4.93
4	10	4.14	0.04	2.72
All	40	4.18	0.02	3.61

Table 8. Means, standard errors, and coefficients of variation for plot weighted averages for each replication and all replications of each hydric soil.

Rep	n	Mean	Std. Error	C.V.
			Flom Soil	
1	10	3.94	0.07	5.58
2	10	3.82	0.12	10.30
3	10	3.80	0.06	5.25
4	10	3.85	0.04	3.21
All	40	3.85	0.04	6.49
			Hoven Soil	
1	10	4.48	0.10	7.31
2	10	3.75	0.14	11.78
3	10	1.82	0.11	19.36
4	10	1.78	0.12	21.53
All	40	2.96	0.20	42.43
			Parnell Soil	
1	10	2.04	0.04	5.79
2	10	1.30	0.07	18.00
3	10	1.56	0.07	13.17
4	10	1.00	0.00	0.00
All	40	1.48	0.07	28.26
			Southam Soil	
1	10	1.00	0.00	0.00
2	10	1.01	0.01	2.09
3	10	1.00	0.00	0.00
4	10	1.00	0.00	0.00
All	40	1.00	0.00	1.05

(Continued)

Table 8. (Concluded)

Rep	n	Mean	Std. Error	C.V.
		Tetonka Soil		
1	10	2.87	0.28	31.37
2	10	2.17	0.15	22.04
3	10	2.39	0.19	25.64
4	10	2.39	0.10	13.11
All	40	2.46	0.10	26.30
		Vallers Soil		
1	10	3.29	0.11	10.87
2	10	3.02	0.13	13.92
3	10	2.21	0.06	8.06
4	10	2.58	0.27	32.60
All	40	2.78	0.10	23.26
		Worthing Soil		
1	10	1.44	0.08	17.91
2	10	1.07	0.02	4.99
3	10	1.14	0.05	13.30
4	10	1.26	0.06	15.27
All	40	1.23	0.04	18.21

"gray area" and only one that was clearly in the range of wetland (Table 8). Hoven, on the other hand, had two reps that were strongly upland in character (both from the same polypedon) and two that were strongly wetland (both from the same polypedon) (Table 8). The overall soil means for Hoven and Vallers are well into the "gray area", while Flom's was strongly upland. Species lists for these soils are found in Appendicies E-8 through E-10.

It is apparent that some of the wetland indicator ratings on the WPL (Reed, 1986) are in error. We have suggested revisions in the ratings of 10 species (Appendix F) and hope that by using these "new ratings" some of the "problem soils" will be better classified. In addition, the use of the UA method, instead of the WA method, might also improve the classification. Even though the ratings in the WPL are designed to indicate a plant's degree of wetland or upland affinity, they were assigned to species based, for the most part, on the subjective opinions of the list's reviewers. Critical studies on the majority of these species have not been conducted. Dix and Smeins (1967) found that only 48 species (18%) of 268 could be used as true indicators of landscape position. This would imply that a majority of the species encountered in the present study may be useless in classifying hydric soils. The design of the present study did not allow us to determinate a plant's usefulness as an indicator. However, based on the premise that at least facultative species (rating of 3) should be truly non-informative, we decided to exclude them from analysis. We hoped this would improve accuracy of the method. After these changes the data were analyzed in three additional ways: (1) UA method using the NWI ratings as was previously done using WA, (2) WA method using the suggested "new ratings" and deleting the facultative species from analysis, and (3) UA method using our "new ratings" and deleting facultative species.

The use of UA methodology would be very time saving. WAs, requiring canopy coverage estimates are very time consuming due to the large number of graminoid plants and high densities at which they typically occur in these habitats. If the use of UAs would be at least as accurate as WAs in separating wetlands from uplands, then it would probably be the methodology of choice. A comparison of the UA method with the WA methods is presented in Table 9. The effect of using UAs was to either significantly increase (Barnes and Svea) or decrease (Hand) the means of the upland soils slightly. For four out of the seven hydric soils, the UA means were not different from the WA means, and for three hydric soils, the UA means were slightly but significantly higher than their WA means. Although the slight increases were significant, and this may signal that caution may be needed before recommending use of UAs, the increases were such that conclusions drawn from either set of means would remain the same. If increases of the same magnitude that occurred on Parnell, Tetonka, and Worthing soils, were to occur on soils with means on the upper end of the "wetland" range (i.e., closer to 3), then conclusions could possibly have been affected. Thus, based on these few soils, it would seem that further testing of the UA method may be required before its use can be recommended.

Table 9. Comparison of means (paired t-test, n = 40 pairs) of the weighted average and unweighted average method using the original "NWI" methods.

Soil	Wtd.Ave. Method	Unwtd.Ave. Method	Sig. (p<)	Direction
Barnes	4.30	4.38	0.0001	+
Hand	4.58	4.34	0.0001	-
Svea	4.18	4.24	0.0001	+
Flom	3.85	3.81	ns	0
Hoven	2.96	2.91	ns	0
Vallers	2.78	2.80	ns	0
Parnell	1.48	1.55	0.002	+
Southam	1.00	1.00	ns	0
Tetonka	2.46	2.66	0.0003	+
Worthing	1.23	1.47	0.0001	+

A comparison of the NWI, WA method with the WA method using our suggested "new" ratings and deleting the facultative species is presented in Table 10. The effect of our "new" method was variable on the upland soils; it significantly increased one mean, significantly decreased another, and had no effect on the third mean. For the hydric soils, the effect was not significant for the Flom or Southam soils, but for all others the "new" method significantly decreased the means. These results cause us to conclude that the revisions made in species ratings and the exclusion of facultative species from analysis is improving the ability of the WA method to distinguish wetland from upland communities.

The use of the UA methodology with our suggested "new" ratings and deleting facultatives has been done and compared to the "new" method using WAs in Table 11. The effect of using UAs instead of WAs on the "new" methodology was the same as on the original "NWI" methodolgy, i.e., UAs were either not different, than their respective WAs, or slightly, but significantly higher -- a situation that is not desirable but may or may not have any practical relevance. Hence, the UA methodology may need some further testing before its use can be recommended.

The data from all plots on each soil were subjected to analysis of variance using a nested classification (reps nested within soils), and soil means were tested with the Waller-Duncan K-ratio t-test. This statistical analysis was performed on all four previously described methods of vegetation analysis. The results of the WA method, using both the NWI original ratings and using the new ratings (Appendix F) with facultatives deleted, are presented in Table 12. The analysis of the data expressed in original NWI ratings shows that the mean WA of the Flom soil is not significantly different from two of the upland soils. It also shows that even though the Hoven and Vallers soils are in the "gray area," they are not significantly different from the Tetonka soil, which is marginally below the "gray area." Using our suggested ratings for 10 species and deleting the facultatives caused all of the communities found on hydric soils, except the Flom, to drop slightly in value and to clarify the groupings. Rather than four groupings, as in the analysis of the original NWI ratings, the means were placed into three distinct groups. The conclusions, however, remain the same: the Flom was still grouped with the upland soils, and the Vallers and Hoven soils are still in the "gray area" and not significantly different from the Tetonka soil. The minimum distance between means needed to detect differences dropped slightly using the second method.

Using the original NWI ratings, the UA soil means were placed into five groups (Table 13). The Flom soil was still grouped with two upland soils. In comparison with the original WA method, the effect of the UA method on the hydric soil means was variable; some increased and some decreased slightly. The Hoven, Vallers, and Tetonka soils were still grouped the same, but the Tetonka mean moved into the "gray area." The effect of using the new ratings and dropping the facultatives on the UA means in comparison to the UA means of the original NWI ratings was the same as in the WA method. The hydric soil means (except the Flom) dropped

Table 10. Comparison of means (paired t-test, n = 40 pairs) of original "NWI" weighted average method with "new" method (i.e., using suggested ratings changes and deleting facultatives).

Soil	Weighted Averages NWI Method	"New" Method	Sig. (p<)	Direction
Barnes	4.30	4.32	ns	0
Hand	4.58	4.28	0.0001	-
Svea	4.18	4.27	0.0002	+
Flom	3.85	3.90	ns	0
Hoven	2.96	2.65	0.0001	-
Vallers	2.78	2.69	0.01	-
Parnell	1.48	1.35	0.0005	-
Southam	1.00	1.00	ns	0
Tetonka	2.46	2.30	0.0001	-
Worthing	1.23	1.20	0.01	-

Table 11. Comparison of means (paired t-test, n = 40 pairs) of the weighted average and unweighted average methods using the "new" method (i.e., using suggested rating changes and deleting facultatives).

Soil	Wtd.Ave. Method	Unwtd.Ave. Method	Sig. (p<)	Direction
Barnes	4.32	4.36	0.0001	+
Hand	4.28	4.24	ns	0
Svea	4.27	4.31	0.0002	+
Flom	3.90	3.95	0.03	+
Hoven	2.65	2.67	ns	0
Vallers	2.69	2.71	ns	0
Parnell	1.35	1.35	ns	0
Southam	1.00	1.00	ns	0
Tetonka	2.30	2.47	0.0006	+
Worthing	1.20	1.43	0.0001	+

Table 12. Comparison of ranked soil means using weighted average methods (n = 40 for each soil; means not followed by the same letter are significantly different, $p < 0.05$; ANOVA with reps nested within soils using Waller-Duncan K-ratio t-test).

NWI Ratings		Suggested Ratings & Facultatives Deleted	
Soil	Means	Soil	Means
Hand	4.58a	Barnes	4.32a
Barnes	4.30ab	Hand	4.28a
Svea	4.18ab	Svea	4.27a
Flom	3.85b	Flom	3.90a
Hoven	2.96c	Vallers	2.69b
Vallers	2.78c	Hoven	2.65b
Tetonka	2.46c	Tetonka	2.30b
Parnell	1.48d	Parnell	1.35c
Worthing	1.23d	Worthing	1.20c
Southam	1.00d	Southam	1.00c
(min. sig. dif. = 0.65)		(min. sig. dif. = 0.56)	

Table 13. Comparison of ranked soil means using unweighted average methods ($n = 40$ for each soil; means not followed by the same letter are significantly different, $p < 0.05$; ANOVA with reps nested within soils using Waller-Duncan K-ratio t-test).

NWI Ratings		Suggested Ratings & Facultatives Deleted	
Soil	Means	Soil	Means
Barnes	4.38a	Barnes	4.36a
Hand	4.34ab	Svea	4.31a
Svea	4.24ab	Hand	4.24a
Flom	3.81b	Flom	3.95a
Hoven	2.91c	Vallers	2.71b
Vallers	2.80c	Hoven	2.67b
Tetonka	2.66c	Tetonka	2.47b
Parnell	1.55d	Worthing	1.43c
Worthing	1.47de	Parnell	1.35c
Southam	1.00e	Southam	1.00c
(min. sig. dif. = 0.54)		(min. sig. dif. = 0.49)	

slightly and three distinct groups formed. Tetonka dropped out of the "gray area" but remained grouped with the Vallers and Hoven soils.

Based on the above analyses, it seems that using the WA method, along with re-rating the species and dropping facultatives from analysis, was the best way to express the data. It yielded three distinct groupings, and produced the lowest means for the hydric soils except the Flom. This suggests that some species that do not yield useful information for classification (i.e. facultatives) should be excluded from analysis. Species need to be initially rated as accurately as possible. We suggest revisions in the ratings of 10 species. Our reasons for re-rating these species are discussed in Appendix E. We found that Bromus inermis and Rosa arkansana, both unrated by the WPL (Reed, 1986) and therefore rated as obligate upland species, were found on soils that are definitely wetland soils. These species were probably present in these situations as relicts due to preceding years of low moisture conditions, which is a normal situation in the glaciated prairies. There are probably many species on the WPL that need revision and those that are truly non-informative should be re-rated as facultatives. As Dix and Smeins (1967) found, most species are probably non-informative. It would seem that an intensive study over a large area would be needed to better select true indicator species.

Further Discussion of the "Problem Soils"

Those soils that typically occupy the depression bottoms (Southam, Parnell, Worthing and Tetonka--although in the two wetlands studied the Tetonka soils were not in the very bottom, but in the area immediately surrounding the very bottom) were correctly classified by the WA methods as wetland. The "problem" soils, Flom, Hoven, and Vallers, are those that are typically found on the edges of these prairie wetlands. The species composition along the transects on the Flom and Vallers soils are indicative of the low prairie zone described by Stewart and Kantrud (1971) that Cowardin et al. (1979) considered to be non-wetland. However, many species associated with temporary wetlands (Stewart and Kantrud, 1971) were also found in Vallers plots. The species found on the Flom transects are indicative of those found within that soil because the polypedons used were narrow enough to be covered by randomly selected plots on the upslope-downslope range in elevation. The Vallers polypedons, on the other hand, were wider. It was observed that the downslope portions of Vallers polypedons had temporary wetland species growing on them, while the upslope portions were obviously upland in character.

The wetland to upland transitional nature of the Vallers soil can be seen in the data listed in Table 14. This table presents the frequency of occurrence, by rating, of species in the plots that were located downslope from the transect and upslope from the transect (see methods section) using both the original NWI ratings and the suggested "new ratings" (Appendix E). Both obligate hydrophytes and facultative wetland species occurred on all transects and on both sides. However, the large frequencies of facultative upland species overshadow the effect of the wetland species in all reps but rep 3 (see WAs in Table 8). The frequencies of wetland species are definitely higher on the downslope plots of reps 1 and 2 than on the

Table 14. Frequency of occurrence by indicator rating of plant species found on four replications of Vallers soil (n=5 plots each per rep for downslope and upslope).

Replication	Indicator rating	Downslope NWI	Downslope New	Upslope NWI	Upslope New	Totals NWI	Totals New
1	1	6	5	2	2	8	7
	2	10	6	7	5	17	11
	3	10	21	6	13	16	34
	4	28	22	30	25	58	47
	5	0	0	5	5	5	5
2	1	15	13	6	5	21	18
	2	21	19	15	13	36	32
	3	7	16	6	14	13	30
	4	23	21	29	28	52	49
	5	3	0	4	0	7	0
3	1	27	24	27	25	54	49
	2	11	11	8	7	19	18
	3	16	24	9	17	25	41
	4	13	9	20	17	33	26
	5	1	0	2	0	3	0
4	1	N/A*	N/A	N/A	N/A	34	31
	2	N/A	N/A	N/A	N/A	22	20
	3	N/A	N/A	N/A	N/A	9	21
	4	N/A	N/A	N/A	N/A	54	47
	5	N/A	N/A	N/A	N/A	1	1

* Plots on this rep were not collected in a manner in which upslope and downslope comparisons could be made.

upslope plots, indicating the transitory nature of the vegetation on this soil.

The effect of the higher hydrophyte frequencies on the downslope plots was to significantly decrease the WA mean on the downslope plots in comparison to the upslope plots; statistically significant on reps 1 and 2, regardless of method (Table 15). The difference between the upslope and downslope WAs on rep 1 by either method was 0.47 units, which caused the value to go from marginally outside the "gray area" to solidly within the "gray area." The effect of slope position was even more pronounced on rep 2 where the WAs averaged from 0.57 units to 0.70 units lower on the downslope side, depending on the method of analysis. The mean WA for rep 2 dropped from well above 3 to well below 3, but stayed within the "gray area" at both positions.

The outlet elevations of the depressions that the Vallers soils surround on the study sites are such that water can only pond the lower portions of the polypedons. Excepting the possibility of snow drift blockage in the outlets in early spring, it is physically impossible for the upper portions of the Vallers polypedons to become inundated. However, where the depressions are fully ponded it might be possible for the upslope portions of these soils to become saturated to the surface due to water movement caused by matric and possibly osmotic potential gradients and with the assistance of evapotranspiration after the growing season starts. The slight effervescence at the soil surface and the violent effervescence in the subsurface horizons (Table 3) is evidence of these phenomena. The periods of ponding or saturation are probably long enough for the development of hydrophytes, but short enough not to discourage facultative upland species. The wetland "edge" obviously occurs somewhere on these Vallers polypedons.

The Flom soils on our areas were all situated around the rims of potholes containing individual temporary wetlands. The fact that the Flom soil had no effervescence in the top three horizons (Table 3) is evidence that duration of inundation or saturation is short and probably preceeds the growing season in most years, so that the effects of evapotranspiration on the upward movement of water is minimal. The low frequencies of obligate hydrophytes and facultative wetland species (Table 16) are supportive of this hypothesis. The discrepancy between frequencies of obligate and facultative wetland species on the downslope versus upslope plots on this soil is slight (Table 16), indicating fairly constant hydrological conditions across these narrow polypedons. The lower CVs of the WA analysis (Table 8) of this soil as compared to the CVs of Vallers (Table 8) are also indicative of a more constant environment. Even though the mean WAs on downslope plots were significantly less than the upslope plots on three out of four Flom reps using the "NWI" method, they were not low enough to be included in the "gray area" (Table 17). Only one significant difference occurred when the data were analyzed using the "new" method, and all downslope means were still above 3.5 (Table 17).

Table 15. Upslope versus downslope weighted average comparisons (paired t-test, n = 5 pairs) on polypedons (reps) of Vallers soil.

Rep	Upslope	Downslope	Sig
	Using original "NWI" method		
1	3.53	3.06	$p<0.03$
2	3.30	2.73	$p<0.02$
3	2.25	2.17	ns
	Using "New" ratings & deleting facultatives		
1	3.59	3.12	$p<0.04$
2	3.31	2.61	$p<0.003$
3	1.95	1.78	ns

Table 16. Frequency of occurrence by indicator rating of plant species found on four replications of Flom soil (n=5 plots each for downslope and upslope).

Replication	Indicator Rating	Downslope NWI	Downslope New	Upslope NWI	Upslope New	Totals NWI	Totals New
1	1	1	1	1	1	2	2
	2	4	3	5	3	9	6
	3	9	15	1	8	10	23
	4	34	35	42	44	76	79
	5	6	0	12	5	18	5
2	1	4	4	0	0	4	4
	2	4	0	0	0	4	0
	3	2	12	1	6	3	18
	4	26	20	30	27	56	47
	5	3	3	7	5	10	8
3	1	1	1	0	0	1	1
	2	9	6	7	4	16	10
	3	9	17	7	15	16	32
	4	36	36	27	24	63	60
	5	7	2	16	14	23	16
4	1	0	0	0	0	0	0
	2	5	0	4	0	9	0
	3	2	12	2	12	4	24
	4	24	19	26	22	50	41
	5	3	3	6	4	9	7

Table 17. Upslope versus downslope weighted average comparisons (paired t-test, n = 5 pairs) on polypedons (reps) of Flom soil.

Rep	Upslope	Downslope	Sig
Using original "NWI" method			
1	4.03	3.85	ns
2	4.08	3.56	p<0.03
3	3.93	3.68	p<0.04
4	3.93	3.77	p<0.04
Using "New" ratings & deleting facultatives			
1	3.92	3.73	ns
2	4.09	3.56	ns
3	4.08	3.68	p<0.03
4	4.08	4.05	ns

The favorable hydrologic conditions at the Deuel County site over the last few years would lead to the speculation that maximal hydrophytic development should have occurred on these soils. However, a lag time may be associated with maximum local watertable height following the groundwater recharge events of the last few years. Therefore it is possible that the best conditions for attainment of maximal hydrophytic development due to a high watertable had not yet occurred. Nonetheless, the vegetation occurring on the Flom polypedons at the time of the study indicate non-wetland habitat.

The vegetation of the two Hoven polypedons that were studied were not nearly as alike in terms of WAs (Table 8) or frequency of obligate and facultative wetland species (Table 18) as were the polypedons (reps) of each of the Flom and Vallers soils. The polypedon at the Brecken Slough GPA site containing reps 3 and 4 was situated on a nearly level slope with its elevation only slightly above the very bottom of the depression where the Worthing soil was located. The polypedon shape was approximately elliptical (about 30 m x 15 m) and the matting and crusting of the fallen plant litter throughout the polypedon were indicative of standing water earlier in the season. The wetland nature of the vegetation was obvious (Tables 8 and 18). The polypedon of the Hoven soil at the Andresen WPA site was long and linear in shape, just a few meters wide, and on the rim of the depression in an area of sharply increasing elevation. The appearance of the litter on this polypedon suggested that inundation occurred on only a few downslope plots on rep 2. The frequencies of obligate and facultative wetland species on downslope versus upslope plots on these reps do not indicate a very rapidly changing species composition (Table 18). Likewise, the mean upslope versus downslope WAs (Table 19) were not significantly different on reps 1 and 2. It should be remembered that this site was situated in a degenerated stand of "dense nesting cover" that had been invaded by a nearly solid stand of Bromus inermis, a very aggressive invader and an introduced cool-season grass. It has been reported that mature plants of this species can withstand early spring flooding (i.e., where temperatures are cold) for 24 to 28 days and that seedlings and seeds can withstand longer periods (Bolton and McKenzie, 1946). It has also been reported for other species of tame forages that tolerance to inundation is greatest under cold temperatures (McKenzie, 1951). It would seem reasonable to assume that Bromus inermis could possibly persist on sites in this situation for a long time if only exposed to brief periods of early spring flooding.

The diverse vegetation situations found on the three wetland edge soils studied indicates that much work needs to be done concerning the definition of wetlands. All three of the wetland edge soils studied are classified as hydric soils according to the criteria of the NTCHS (1986). However, the vegetation found on the Flom soils indicates non-wetland conditions. The vegetation found on the Vallers soils were true mixtures of upland and wetland species and thus largely fell into the "gray area" according to Wentworth and Johnson (1986). The Hoven soils represented both extremes as one polypedon was obviously wetland and one polypedon was obviously upland based on the species present. The definition of wetlands according to Cowardin et al. (1979) states that:

Table 18. Frequency of occurrence by indicator rating of plant species found on four replications of Hoven soil (n=5 plots each for downslope and upslope).

Replication	Indicator rating	Downslope NWI	Downslope New	Upslope NWI	Upslope New	Totals NWI	Totals New
1	1	1	1	1	1	2	2
	2	1	1	2	2	3	3
	3	0	1	3	3	3	3
	4	7	12	5	10	12	22
	5	5	0	5	0	10	0
2	1	6	5	4	4	10	9
	2	1	2	1	1	2	3
	3	1	3	2	4	3	7
	4	17	22	9	12	26	34
	5	7	0	6	1	13	1
3	1	N/A*	N/A	N/A	N/A	32	28
	2	N/A	N/A	N/A	N/A	10	14
	3	N/A	N/A	N/A	N/A	0	1
	4	N/A	N/A	N/A	N/A	11	12
	5	N/A	N/A	N/A	N/A	4	2
4	1	N/A	N/A	N/A	N/A	32	29
	2	N/A	N/A	N/A	N/A	13	16
	3	N/A	N/A	N/A	N/A	0	8
	4	N/A	N/A	N/A	N/A	16	11
	5	N/A	N/A	N/A	N/A	3	0

* The polypedon from which these data were collected were not suitable for downslope-upslope comparisons.

Table 19. Upslope versus downslope weighted average comparisons (paired t-test, n = 5 pairs) on polypedons (reps) of Hoven soil.

Rep	Upslope	Downslope	Sig
	Using original "NWI" method		
1	4.47	4.48	ns
2	3.81	3.69	ns
	Using "New" ratings & deleting facultatives		
1	3.82	3.83	ns
2	3.33	3.32	ns

> "...wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Thus, by Cowardin et al. (1979) criteria, all of the "problem" sites are wetland by virtue of the soils being on the HSL. A major objective of this study, however, was to evaluate the suitability of the investigated soils for their inclusion on the list. Using the vegetation data as collaborative information, we have shown that some polypedons of both Vallers and Hoven soils do support a predominance of hydrophytes. Therefore, the placement of these two soils on the HSL is warranted. On the other hand, none of the Flom polypedons studied supported a predominance of hydrophytes under the conditions occurring at the time of study. Whether or not the Flom sites would "at least periodically" support a predominance of hydrophytes is not known and would require long-term study. However, based on the knowledge that water conditions at the sites had been excellent for the previous two years, it seems reasonable to speculate that the Flom sites may not periodically support predominantly hydrophytes and is a candidate for possible removal from the state HSL.

It would appear that due to the genetic variability of plants, ecotypes and biotypes of many species probably exist that may confound attempts to use them as indicator species. In addition, the range of plant communities found on Vallers and Hoven soils indicates that some species of plants may be intolerant to slight variations in hydrologic regime, while others are relatively tolerant of variation.

The review of the literature, contained earlier in this report, has already established that distribution of species in these wetlands is heavily influenced by disturbance; changing water-regime probably being the most frequent type. At points well within the wetland boundaries, year to year variation in species composition due to fluctuating water levels will occur, but variations will typically include other hydrophytes. The shifts in species occurring at the wetland edge however will include both hydrophytes and upland species. Where the shift actually occurs on the landscape at a given point in time will reflect the current set of hydrological conditions as well as those of recent past. The soil, on the other hand, reflects the average hydrological conditions present over pedological time. The only exception is where artificial drainage changes the aquic moisture regime to non-aquic. The soil properties which are indicators of wetness (mottling and low chroma colors) may require several centuries to change (Moorman and van de Wetering, 1984). If wetland edges characteristically occur on certain soil types, then it would seem that the extent of those soil polypedons would delineate the long-term average of the wetland edge, regardless of the present species occurrence. Of course, this assumes that the pedological processes occurring at the wetland edge are also the major processes throughout the polypedon. Studies should be

conducted that concentrate on the processes occurring at the wetland edge so that wetland edge soils might be used for delineation of the wetland boundary.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

(1) Our data showed that Flom, Vallers, Parnell, Southam, Hoven, Tetonka, and Worthing soils were hydric. Flom and Vallers soils were classified as hydric according to criteria 2B2 (Appendix A). These two soils are seldom ponded due to their landscape position. The soil data indicated that the watertable is almost always within 1.5 feet from the soil surface in the early spring.

(2) Parnell, Hoven, Tetonka, and Worthing soils were classified as hydric according to criteria 2B2 and/or 3 (Appendix A). These four soils had well developed Bt horizons due to the many wetting and drying cycles that are common with these soils. The high watertable found with these soils caused gleying of the native color of the peds. These soils are ponded in the spring depending on the snowmelt runoff, spring precipitation, and the watertable level going into the previous winter. Because ponding is dependent upon these natural events, it may not occur every year.

(3) Southam soil was classified hydric according to criteria 3 (Appendix A). Southam soil is typically ponded throughout most of the growing season because it is found in semipermanent dominated wetlands. Southam soil had little soil development due to the chemically reduced and waterlogged conditions found in their environment.

(4) Published soil surveys for this region generally do not contain sufficient detail to be used to identify the exact location of most wetland soils. Mapping units used are at too large of a scale.

(5) The weighted average (WA) approach of vegetation analysis correctly classified Barnes, Hand, and Svea soils as upland sites (WAs >3.5). When averaged over all four reps, it classified Southam, Parnell, Worthing, and Tetonka soils as wetland sites (WAs <2.5). Flom soil, however was classified as upland (WA >3.5) while the other two wetland edge soils (Hoven and Vallers) were classified as "gray area" sites (WAs >2.5 and <3.5); i.e., neither strongly hydric or upland.

(6) There appears to be little difference between results of the weighted average (WA) and unweighted average (UA) methods of vegetation analysis. When significant differences did occur between the WA and UA means for the hydric soils sites, the UA means were always slightly higher than the WA means. Based on this apparent bias, we conclude that the UA method should be further tested on another set of hydric soils in this region before its use is recommended.

(7) The use of revised species ratings and deletion of facultative species from analysis significantly lowered the mean weighted averages of the vegetation communities on all hydric soils except Flom and Southam. The use of revised species ratings and deletion of facultative species from the vegetation analysis caused the multiple range tests of both weighted average and unweighted average soil means to classify the soils into three distinct groups (as opposed to four or five groups using the original NWI ratings): (a) upland sites, which include the hydric Flom soil, (b) wetland sites (Parnell, Southam, Tetonka and Worthing soils), and (c) "gray area" sites (Hoven and Vallers soils) that were not significantly different from Tetonka soil which had a mean weighted average value in the wetland catagory (WA <2.5). Based on these statistical tests, we conclude that a critical evaluation of the NWI indicator ratings for species on the WPL and those not on the WPL is needed.

(8) Due to the constant changing nature of prairie wetland vegetation, the use of soils in the delineation of wetlands in this region would probably be the most accurate method. The "problem soils" are those that occur (at least of those soils studied) at the wetland edge. Studies are needed to determine if these wetland edge soils can be used to delimit the extent of the flucuating location of the wetland boundary.

RECOMMENDATIONS

(1) A frequency factor of 50% (five years out of ten; the same frequency used by the NTCHS [1986] for flooding) for ponding and watertable height should be included in the criteria for hydric soil. This would alleviate the following problems: (a) when the watertable depth does not occur within 1 or 1.5 feet from the soil surface every year (criteria 2A, 2B1, and 2B2 in Appendix A), (b) when the soil is not ponded every year for a long or very long duration (criteria 3 in Appendix A), and (c) when mottles are not formed because of oxidized water during saturation and/or the soil temperature is below 5 C when the soil is saturated.

(2) Studies such as those described in this report should be continued and expanded in the glaciated prairie region. That is, the approach of describing the plant communities within soil polypedons should be maintained as this will identify the soils which need further study. In this pilot study, it was only possible to study six out of the 70 soil series listed on the state's HSL (plus the hydric Southam soil).

(3) Further testing of the unweighted average method should be conducted to determine if its upward bias is of practical significance. If the unweighted average method could be used, much time in the field could be saved. The 0.5 X 1.0m plot size worked satisfactorily in this investigation, however the variability of species occurrence on some soils (notably the Vallers) may require that more plots or a more dispersed type of sampling design be used.

(4) Additional study needs to be made of the wetland edge. It needs to be determined if those hydrologic conditions present at the wetland edge are responsible for the formation of the soil series that occur at the wetland-upland boundary, and if those soil series occurring at the edge can be used to set the limits of wetlands.

(5) If plant species are to be used to delineate wetlands, then a critical study of both wetland and upland indicator species is needed.

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GLOSSARY OF SOIL TERMS

Albic Horizon. A mineral soil horizon from which clay and free iron oxides have been removed or in which the oxides have been segregated to the extent that the color of the horizon is determined primarily by the color of the primary sand and silt particles instead of by coatings on these particles.

Aquic. A mostly reducing soil moisture regime nearly free of dissolved oxygen due to saturation by ground water or its capillary fringe and occurring at periods when the soil temperature at 50 centimeters is above 5 degrees Celsius.

Argillic Horizon. A mineral soil horizon that is characterized by the illuvial accumulation of layer-lattice silicate clays. The argillic horizon has a certain minimum thickness, depending on the thickness of the solum, a minimum quantity of clay in comparison with an overlying eluvial horizon depending on the clay content of the eluvial horizon, and usually has coatings of oriented clay on the surface of pores or peds or bridging sand grains.

Calcareous Soil. Soil containing sufficient free calcium carbonate or calcium-magnesium carbonate to effervesce visibly when treated with cold 0.1 N hydrochloric acid.

Calcic Horizon. A mineral soil horizon of secondary carbonate enrichment that is more than 15 centimeters thick, has a calcium carbonate equivalent of more than 15 percent, and has at least 5 percent more calcium carbonate equivalent than the underlying C horizon.

Channel Cutans. Associated with the walls of channels whether these be of biological origin (worm channels, etc.) or not.

Channel Ferrans. Iron oxides or hydroxides found along macropores, espicially root channels. Produced by plants adding oxygen to saturated soil around the roots.

Chroma. The relatively purity, strength, or saturation of a color; directly related to the dominance of the determining wavelength of the light and inversely related to grayness: one of the three variables of color.

Gley Soil. Soil developed under conditions of poor drainage, resulting in reduction of iron and other elements and in gray colors and mottles.

Hue. One of the three variables of color. It is caused by light of certain wavelengths and changes with the wavelength.

Illuvial Horizon. A soil layer or horizon in which material carried from an overlying layer has been precipitated from solution or deposited from suspension. The layer of accumulation.

Illuviation. The process of deposition of soil material removed from one horizon to another in the soil; usually from an upper to a lower horizon in the soil profile.

Matrix Color. The single dominant color of a soil horizon.

Mollic Epipedon. A surface horizon of mineral soil that is dark colored and relatively thick, contains at least 0.58 percent organic carbon, is not massive and hard or very hard when dry, has a base saturation of more than 50 percent when measured at pH 7, has less than 250 parts per million of P2O5 soluble in 1 percent citric acid, and is dominantly saturated with bivalent cations.

Mollisols. Mineral soils that have a mollic epipedon overlying mineral material with a base saturation of 50 percent or more when measured at pH 7. Mollisols may have an argillic, natric, albic, cambic, gypsic, calcic, or petrocalcic horizon, a histic epipedo, or a duripan, but not an oxic or spodic horizon. (An order in the USDA soil taxonomy.)

Mottling. Spots or blotches of different color or shades of color interspersed with the dominant color.

Munsell Color System. A color designation system that specifies the relative degrees of the three simple variables of color: hue, value, chroma. For example: 10YR 6/4 is a color (of soil) with a hue = 10YR, value = 6, and chroma = 4.

Natric Horizon. A mineral soil horizon that satisfied the requirements of an argillic horizon, but that also has prismatic, columnar, or blocky structure and a subhorizon having more than 15 percent saturation with exchangeable sodium.

Parent Material. The unconsolidated and more or less chemically weathered mineral or organic matter from which the solum of soil is developed by pedogenic processes.

Ped. A unit of soil structure such as an aggregate, crumb, prism, block, or granule, formed by natural processes (in contrast with a clod, which is formed artificially).

Pedon. The three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations. Its area ranges from 1 to 10 square meters.

Polypedon. Contiguous pedons, all falling within the defined range of a single soil series.

Profile, Soil. A vertical section of the soil through all its horizon and extending into the parent material.

Rhizosphere. The zone of soil where the microbial population is altered both quantitatively and qualitativly by the presence of plant roots.

Sodium Adsorption Ratio (SAR). A relation between soluble sodium and soluble divalent cations that can be used to predict the exchangeable sodium percentage of soil equilibrated with a given solution.

$$SAR = Na/[(Ca + Mg)/2)]1/2$$

Soil Association. (1) A group of defined and named taxonomic soil units occuring together in an individual and characteristic pattern over a geographic region. (2) A mapping unit used on general soil maps, in which two or more defined taxonomic units occurring together in a characteristic pattern are combined because the scale of the map or the purpose for which it is being made does not require delineation of the individual soils.

Soil Horizon. A layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layer in physical, chemical, and biological properties or characteristics such as color, structure, texture, consistency, kinds and numbers of organisms present, degree of acidity or alkalinity, etc.

Solum. (plural: Sola). The upper and most weathered part of the soil profile; the A and B horizon.

Toposequence. A sequence of related soils that differ, one from the other, primarily because of topography as a soil-formation factor.

Value, Color. The relative lightness or intensity of color and approximate a function of the square root of the total amount of light. One of the three variables of color.

APPENDIX A

HYDRIC SOIL DEFINITION AND CRITERIA

HYDRIC SOIL DEFINITION AND CRITERIA

The National Technical Committee for Hydric Soils (1986) defines a hydric soil as a soil that in is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation.

The criteria for hydric soil is as follows:

1) All Histosols except Folists, or
2) Soils in Aquic suborders, Aquic subgroups, Salorthids great group, or Pell great groups of Vertisols that are:
    a) somewhat poorly drained and have watertable less than 0.5 ft. from the surface for a significant period (usually a week or more) during the growing season, or
    b) poorly drained or very poorly drained and have either:
        (1) water table at less than 1.0 ft. from the surface for a significant period (usually a week or more) during the growing season if permeability is equal to or greater than 6.0 in/hr in all layers within 20 inches, or
        (2) water table at less than 1.5 ft. from the surface for a significant period (usually a week or more) during the growing season if permeability is less than 6.0 in/hr in any layer within 20 inches, or
3) Soils that are ponded for long duration or very long duration during the growing season, or
4) Soils that are frequently flooded for long duration or very long duration during the growing season.

APPENDIX B

DEFINITIONS OF SOIL MORPHOLOGY ABBREVIATIONS USED

DEFINITIONS OF SOIL MORPHOLOGY ABBREVIATIONS USED

BOUNDARY DISTINCTNESS

Boundary distinctness is an assessment of the distance of change of the lower boundary of the horizon being described into the lower horizon. The terms used are:

a-abrupt- change of less than 2 cm thickness
c-clear- change of 2-5 cm thickness
g-gradual- change of 5-15 cm thickness
d-diffuse- change of >15 cm thickness

TEXTURE

Soil texture refers to the relative proportion of clay, silt, and sand. The twelve textural classes of the USDA texture triangle are:

S-sand	CL-clay loam
LS-loamy sand	SiCL-silty clay loam
Si-silt	SCL-sandy clay loam
L-loam	C-clay
SiL-silty loam	SiC-silty clay
SL-sandy loam	SC-sandy clay

STRUCTURE

Structure is described by grade and type. Terms are used to describe the natural aggregates in the soil (peds).

Grade - structural grade is described as follows:

sl-structureless -no aggregates
w-weak -poorly defined peds which are relatively unstable and difficult to observe
m-moderate -peds are observable and fairly distinct
s-strong -peds are durable and quite evident in undisturbed soil

Type - the form or shape of the structure

g-granular -rounded, spherical peds
abk-angular blocky -peds are approximately equal in width, depth, and height; they have sharp corners and fit together well
sbk-subangular blocky -much like angular blocky but with prominently rounded corners
pr-prismatic -peds are taller than they are deep or

wide; may appear like two or more blocks on top of each other

cpr-columnar -much like prismatic except they have rounded tops

pl-platy -vertical dimension small with regard to horizontal dimensions

m-massive -no aggregates present

sg-single grain -no aggregates present

MOTTLES

Mottles are described by abundance, contrast, and size.

Abundance

f-few -mottles <2% of surface area

c-common -mottles 2-20% of surface area

m-many -mottles >20% of surface area

Contrast

f-faint -mottles are indistinct and difficult to recognize; hue and chroma of matrix and mottles similiar

d-distinct -mottles are readily seen and may vary from the matrix by one or two hue, value, or chroma units

p-prominent -mottles are very striking and conspicuous and vary from the matrix by several hue, value, or chroma units

Size

f-fine - <5 mm in diameter

m-medium - 5-15 mm in diameter

c-coarse - >15 mm in diameter

MOIST CONSISTENCE

Consistence ia measure of the property of a soil to adhere or cohere or to resist deformation or rupture. This property is measured when the soil is moist. The terms used are:

l-loose -noncoherent material

vfr-very friable -peds will break easily with very gentle pressure between thumb and forefinger

fr-friable -peds will crush easily with gentle to moderate finger pressure

fi-firm -peds will require moderate to heavy pressure and will produce a small indentation on skin

vfi-very firm -peds will barely crush between thumb and forefinger

efi-extremely firm -peds are too strong to crush between thumb and forefinger

EFFERVESCENT

Ten percent (about 1N) solution of hydrochloric acid is used to test for carbonates in the field. The amount and violence of effervescence are affected by many factors besides the amount of calcium carbonates. Consequently, the violence of effervescence provides a qualitative description rather than a quantitive estimate of the amount of carbonates. Four classes of effervescence are used to describe the results of the test.

eo -none to very slight effervescent (none to few bubbles seen)

e -slight effervescent (bubbles readily seen)

es -strongly effervescent (bubbles form low foam)

ev -violently effervescent (thick foam forms quickly)

APPENDIX C

ALPHABETICAL LISTING OF SPECIES CODES, NAMES, AND WETLAND INDICATOR RATINGS OF PLANTS OBSERVED IN THIS STUDY

CODE	NAME	RATING
ACMI2	ACHILLEA MILLEFOLIUM	4
AGIN2	AGROPYRON INTERMEDIUM	5
AGSM	AGROPYRON SMITHII	4
AGTR	AGROPYRON TRACHYCAULUM	5
AGHY	AGROSTIS HYEMALIS	4
AGST2	AGROSTIS STOLONIFERA	2
ALGAE	ALGAE	1
ALPL	ALISMA PLANTAGO-AQUATICA	1
ALLIU	ALIUM SPP	UNKNOWN
ALST	ALLIUM STELLATUM	5
ALAE	ALOPECURUS AEQUALIS	1
AMAL	AMARANTHUS ALBUS	4
AMRE	AMARANTHUS RETROFLEXUS	4
AMAR2	AMBROSIA ARTEMISIIFOLIA	4
AMPS	AMBROSIA PSILOSTACHYA	3
AMROX	AMMANNIA ROBUSTA	1
AMCA6	AMORPHA CANESCENS	5
ANGE	ANDROPOGON GERARDII	4
ANCA8	ANEMONE CANADENSIS	2
ANCY	ANEMONE CYLINDRICA	5
ANNE	ANTENNARIA NEGLECTA	5
APCA	APOCYNUM CANNABINUM	3
ARLU	ARTEMISIA LUDOVICIANA	5
ASIN	ASCLEPIAS INCARNATA	1
ASSP	ASCLEPIAS SPECIOSA	3
ASCLE	ASCLEPIAS SPP	UNKNOWN
ASVE	ASCLEPIAS VERTICILLATA	5
ASER3	ASTER ERICOIDES	4
ASHE	ASTER HESPERIUS	1
ASSE2	ASTER SERICEUS	5
ASAG2	ASTRAGALUS AGRESTIS	4
ASCA11	ASTRAGALUS CANADENSIS	4
ASCR2	ASTRAGALUS CRASSICARPUS	5
ASFL2	ASTRAGALUS FLEXUOSUS	5
ASTRA	ASTRAGALUS SPP	UNKNOWN
BESY	BECKMANNIA SYZIGACHNE	1
BIFR	BIDENS FRONDOSA	2
BOAS	BOLTONIA ASTEROIDES	2
BOCU	BOUTELOUA CURTIPENDULA	5
BRIN2	BROMUS INERMIS	5
CANE	CALAMAGROSTIS NEGLECTA	1
CASE13	CALYSTEGIA SEPIUM	3
CAAT2	CAREX ATHERODES	1
CABR10	CAREX BREVIOR	4
CAGR3	CAREX GRANULARIS	1
CAHE5	CAREX HELIOPHILA	5
CALA12	CAREX LAEVICONICA	1
CALA30	CAREX LANUGINOSA	1
CAPR5	CAREX PRAEGRACILIS	2
CASA8	CAREX SARTWELLII	2
CAREX	CAREX SPP	UNKNOWN
CATE6	CAREX TETANICA	2
CHAL7	CHENOPODIUM ALBUM	3
CIAR4	CIRSIUM ARVENSE	4
CIFL	CIRSIUM FLODMANII	5

CODE	NAME	RATING
COCA5	CONYZA CANADENSIS	4
DAPU5	DALEA PURPUREA	5
DILE2	DICANTHELIUM LEIBERGII	4
ECCR	ECHINOCHLOA CRUSGALLI	2
ECMU2	ECHINOCHLOA MURICATA	1
ELAC	ELEOCHARIS ACICULARIS	1
ELCO2	ELEOCHARIS COMPRESSA	2
ELOB2	ELEOCHARIS OBTUSA	1
ELPA3	ELEOCHARIS PALUSTRIS	1
ELCA4	ELYMUS CANADENSIS	4
EQAR	EQUISETUM ARVENSE	3
EQLA	EQUISETUM LAEVIGATUM	3
EUSE5	EUPHORBIA SERPHYLLIFOLIA	5
GABO2	GALIUM BOREALE	4
GACO5	GAURA COCCINEA	5
GEPU5	GENTIANA PUBERULENTA	5
GETR	GEUM TRIFLORUM	4
GLST	GLYCERIA STRIATA	1
GLLE3	GLYCYRRHIZA LEPIDOTA	4
HEAN3	HELIANTHUS ANNUUS	4
HEMA2	HELIANTHUS MAXIMILIANI	4
HETU	HELIANTHUS TUBEROSUS	4
HEHE5	HELIOPSIS HELIANTHOIDES	5
HERI	HEUCHERA RICHARDSONII	4
HOJU	HORDEUM JUBATUM	2
JUBA	JUNCUS BALTICUS	1
JUIN2	JUNCUS INTERIOR	2
JUTE	JUNCUS TENUIS	3
KOPY	KOELERIA PYRAMIDATA	5
LAPU	LACTUCA PULCHELLA	4
LASE	LACTUCA SERRIOLA	4
LAPA4	LATHYRUS PALUSTRIS	3
LEMI3	LEMNA MINOR	1
LETR	LEMNA TRISULCA	1
LIPU	LIATRIS PUNCTATA	5
LICA12	LITHOSPERMUM CANESCENS	5
LOPU3	LOTUS PURSHIANUS	5
LYAM	LYCOPUS AMERICANUS	1
LYAS	LYCOPUS ASPER	1
MELU	MEDICAGO LUPULINA	4
MEAL2	MELILOTUS ALBA	4
MEOF	MELILOTUS OFFICINALIS	4
MEAR4	MENTHA ARVENSIS	2
MUAS	MUHLENBERGIA ASPERIFOLIA	2
MUME2	MUHLENBERGIA MEXICANA	2
MURA	MUHLENBERGIA RACEMOSA	2
MURI	MUHLENBERGIA RICHARDSONIS	3
ONMO	ONOSMODIUM MOLLE	5
OXST	OXALIS STRICTA	5
PAVI2	PANICUM VIRGATUM	3
PECA	PEDICULARIS CANADENSIS	4
PHAR3	PHALARIS ARUNDINACEA	2
PHPR3	PHLEUM PRATENSE	4
PHVI5	PHYSALIS VIRGINIANA	5
POCO	POA COMPRESSA	4

CODE	NAME	RATING
POPA2	POA PALUSTRIS	2
POPR	POA PRATENSIS	4
POAM8	POLYGONUM AMPHIBIUM	1
POCO10	POLYGONUM CONVOLVULUS	3
POPE2	POLYGONUM PENSYLVANICUM	2
POPU5	POLYGONUM PUNCTATUM	1
PORA3	POLYGONUM RAMOSISSIMUM	4
POAN5	POTENTILLA ANSERINA	1
POAR7	POTENTILLA ARGUTA	4
PSAR2	PSORALEA ARGOPHYLLA	5
PUPA5	PULSATILLA PATENS	5
RARH	RANUNCULUS RHOMBOIDEUS	5
RACO3	RATIBIDA COLUMNIFERA	5
RIFLX	RICCIA FLUITANS	1
RINAX	RICCIOCARPUS NATANS	1
ROPA2	RORIPPA PALUSTRIS	1
ROAC	ROSA ACICULARIS	4
ROAR3	ROSA ARKANSANA	5
RUCR	RUMEX CRISPUS	2
RUME2	RUMEX MEXICANUS	2
RUMEX	RUMEX SPP	UNKNOWN
RUST4	RUMEX STENOPHYLLUS	1
SACU	SAGITTARIA CUNEATA	1
SCSC	SCHIZACHYRIUM SCOPARIUM	4
SCAC	SCIRPUS ACUTUS	1
SCAT2	SCIRPUS ARTOVIRENS	1
SCFL	SCIRPUS FLUVIATILIS	1
SCSA2	SCIRPUS SAXIMONTANUS	1
SCFE	SCOLOCHLOA FESTUCACEA	1
SEPS2	SENECIO PSEUDAUREUS	2
SEGL2	SETARIA GLAUCA	4
SOCA6	SOLIDAGO CANADENSIS	4
SOGI	SOLIDAGO GIGANTEA	2
SORI2	SOLIDAGO RIGIDA	4
SOAR2	SONCHUS ARVENSIS	3
SONU2	SORGHASTRUM NUTANS	4
SPEU	SPARGANIUM EURYCARPUM	1
SPPE	SPARTINA PECTINATA	2
SPAS	SPOROBOLUS ASPER	4
SPHE	SPOROBOLUS HETEROLEPIS	5
STPA	STACHYS PALUSTRIS	1
STSP2	STIPA SPARTEA	5
STVI4	STIPA VIRIDULA	5
SYOC	SYMPHORICARPOS OCCIDENTALIS	5
TAOF	TARAXACUM OFFICINALE	4
TECA3	TEUCRIUM CANADENSE	2
TRDU	TRAGOPOGON DUBIUS	5
TYAN	TYPHA ANGUSTIFOLIA	1
TYGL	TYPHA X GLAUCA	1
UTMA	UTRICULARIA MACRORHIZA	1
VEST	VERBENA STRICTA	5
VEFA2	VERNONIA FASCICULATA	2
VINE	VIOLA NEPHROPHYLLA	2
VIPE2	VIOLA PEDATIFIDA	4
ZIEL2	ZIGADENUS ELEGANS	4
ZIAP	ZIZIA APTERA	4

APPENDIX D

FREQUENCY OF OCCURRENCE OF SPECIES OCCURING IN THE HERBACEOUS STRATUM AT ALL SITES

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POPR	186	6.3	186	6.3
SOCA6	130	4.4	316	10.7
ASER3	124	4.2	440	14.9
AGSM	96	3.2	536	18.1
BRIN2	96	3.2	632	21.4
SCSC	94	3.2	726	24.6
POAM8	91	3.1	817	27.6
ELPA3	90	3.0	907	30.7
ANGE	77	2.6	984	33.3
CATE6	72	2.4	1056	35.7
CALA30	71	2.4	1127	38.1
ASHE	68	2.3	1195	40.4
SORI2	67	2.3	1262	42.7
PUPA5	63	2.1	1325	44.8
AGTR	61	2.1	1386	46.9
BOCU	61	2.1	1447	48.9
AMAR2	51	1.7	1498	50.7
ACMI2	47	1.6	1545	52.2
PAVI2	40	1.4	1585	53.6
SEGL2	39	1.3	1624	54.9
STSP2	39	1.3	1663	56.2
ELAC	38	1.3	1701	57.5
SPPE	37	1.3	1738	58.8
CASE13	36	1.2	1774	60.0
SCAC	36	1.2	1810	61.2
BIFR	33	1.1	1843	62.3
ELCO2	31	1.0	1874	63.4
RUST4	30	1.0	1904	64.4
SONU2	29	1.0	1933	65.4
RUMEX	28	0.9	1961	66.3
AGIN2	27	0.9	1988	67.2
STVI4	27	0.9	2015	68.1
LASE	26	0.9	2041	69.0
DILE2	25	0.8	2066	69.9
CANE	24	0.8	2090	70.7
LEMI3	23	0.8	2113	71.5
RIFLX	23	0.8	2136	72.2
AMAL	22	0.7	2158	73.0
APCA	22	0.7	2180	73.7
SOAR2	22	0.7	2202	74.5
EQLA	21	0.7	2223	75.2
HOJU	21	0.7	2244	75.9
ROAR3	20	0.7	2264	76.6
CAAT2	19	0.6	2283	77.2
CIFL	19	0.6	2302	77.8
MEOF	19	0.6	2321	78.5
HEMA2	17	0.6	2338	79.1
CIAR4	16	0.5	2354	79.6
ECMU2	16	0.5	2370	80.1
LICA12	16	0.5	2386	80.7
LYAM	16	0.5	2402	81.2
LYAS	16	0.5	2418	81.8
MELU	16	0.5	2434	82.3
PHPR3	16	0.5	2450	82.9
SPEU	16	0.5	2466	83.4

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
ANCY	15	0.5	2481	83.9
LETR	15	0.5	2496	84.4
UTMA	15	0.5	2511	84.9
EQAR	14	0.5	2525	85.4
JUBA	13	0.4	2538	85.8
RUME2	13	0.4	2551	86.3
ALGAE	12	0.4	2563	86.7
HEAN3	12	0.4	2575	87.1
PHVI5	12	0.4	2587	87.5
POPA2	11	0.4	2598	87.9
TYGL	11	0.4	2609	88.2
ASAG2	10	0.3	2619	88.6
SCFE	10	0.3	2629	88.9
ANCA8	9	0.3	2638	89.2
BOAS	9	0.3	2647	89.5
POCO10	9	0.3	2656	89.8
PSAR2	9	0.3	2665	90.1
SYOC	9	0.3	2674	90.4
ZIAP	9	0.3	2683	90.7
ARLU	8	0.3	2691	91.0
RUCR	8	0.3	2699	91.3
STPA	8	0.3	2707	91.5
AMROX	7	0.2	2714	91.8
GABO2	7	0.2	2721	92.0
LAPA4	7	0.2	2728	92.3
VIPE2	7	0.2	2735	92.5
ALLIU	6	0.2	2741	92.7
CAHE5	6	0.2	2747	92.9
ELCA4	6	0.2	2753	93.1
JUTE	6	0.2	2759	93.3
KOPY	6	0.2	2765	93.5
MUAS	6	0.2	2771	93.7
POCO	6	0.2	2777	93.9
RINAX	6	0.2	2783	94.1
VEST	6	0.2	2789	94.3
CAPR5	5	0.2	2794	94.5
ELOB2	5	0.2	2799	94.7
HEHE5	5	0.2	2804	94.8
POAN5	5	0.2	2809	95.0
POPU5	5	0.2	2814	95.2
SCFL	5	0.2	2819	95.3
VINE	5	0.2	2824	95.5
ZIEL2	5	0.2	2829	95.7
AMRE	4	0.1	2833	95.8
CAGR3	4	0.1	2837	95.9
GACO5	4	0.1	2841	96.1
POPE2	4	0.1	2845	96.2
SOGI	4	0.1	2849	96.3
AGST2	3	0.1	2852	96.4
ALPL	3	0.1	2855	96.6
CALA12	3	0.1	2858	96.7
DAPU5	3	0.1	2861	96.8
GLLE3	3	0.1	2864	96.9
LAPU	3	0.1	2867	97.0
LOPU3	3	0.1	2870	97.1

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
ONMO	3	0.1	2873	97.2
PHAR3	3	0.1	2876	97.3
SCAT2	3	0.1	2879	97.4
TRDU	3	0.1	2882	97.5
VEFA2	3	0.1	2885	97.6
AGHY	2	0.1	2887	97.6
ALAE	2	0.1	2889	97.7
AMCA6	2	0.1	2891	97.8
AMPS	2	0.1	2893	97.8
ASCLE	2	0.1	2895	97.9
ASTRA	2	0.1	2897	98.0
CABR10	2	0.1	2899	98.0
CHAL7	2	0.1	2901	98.1
COCA5	2	0.1	2903	98.2
ECCR	2	0.1	2905	98.2
EUSE5	2	0.1	2907	98.3
GETR	2	0.1	2909	98.4
MUME2	2	0.1	2911	98.4
MURI	2	0.1	2913	98.5
OXST	2	0.1	2915	98.6
RACO3	2	0.1	2917	98.6
SACU	2	0.1	2919	98.7
SCSA2	2	0.1	2921	98.8
SPHE	2	0.1	2923	98.9
TAOF	2	0.1	2925	98.9
TYAN	2	0.1	2927	99.0
ALST	1	0.0	2928	99.0
ANNE	1	0.0	2929	99.1
ASCA11	1	0.0	2930	99.1
ASCR2	1	0.0	2931	99.1
ASFL2	1	0.0	2932	99.2
ASIN	1	0.0	2933	99.2
ASSE2	1	0.0	2934	99.2
ASSP	1	0.0	2935	99.3
ASVE	1	0.0	2936	99.3
BESY	1	0.0	2937	99.3
CAREX	1	0.0	2938	99.4
CASA8	1	0.0	2939	99.4
GEPU5	1	0.0	2940	99.4
GLST	1	0.0	2941	99.5
HERI	1	0.0	2942	99.5
HETU	1	0.0	2943	99.5
JUIN2	1	0.0	2944	99.6
LIPU	1	0.0	2945	99.6
MEAL2	1	0.0	2946	99.6
MEAR4	1	0.0	2947	99.7
MURA	1	0.0	2948	99.7
PECA	1	0.0	2949	99.7
POAR7	1	0.0	2950	99.8
PORA3	1	0.0	2951	99.8
RARH	1	0.0	2952	99.8
ROAC	1	0.0	2953	99.9
ROPA2	1	0.0	2954	99.9
SEPS2	1	0.0	2955	99.9
SPAS	1	0.0	2956	100.0
TECA3	1	0.0	2957	100.0

APPENDIX E

FREQUENCIES OF OCCURRENCE OF PLANT SPECIES FOUND ON ALL REPLICATIONS OF EACH SOIL

Appendix E-1. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Barnes soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POPR	39	8.7	39	8.7
SORI2	35	7.8	74	16.5
SCSC	33	7.4	107	23.9
AGTR	32	7.1	139	31.0
ASER3	31	6.9	170	37.9
SOCA6	30	6.7	200	44.6
PUPA5	26	5.8	226	50.4
BOCU	25	5.6	251	56.0
AGSM	24	5.4	275	61.4
STSP2	22	4.9	297	66.3
ANGE	18	4.0	315	70.3
ACMI2	12	2.7	327	73.0
STVI4	12	2.7	339	75.7
LICA12	11	2.5	350	78.1
ASAG2	9	2.0	359	80.1
ANCY	6	1.3	365	81.5
CAHE5	6	1.3	371	82.8
MELU	6	1.3	377	84.2
CIAR4	5	1.1	382	85.3
PHVI5	5	1.1	387	86.4
POCO	5	1.1	392	87.5
PSAR2	5	1.1	397	88.6
CATE6	4	0.9	401	89.5
CIFL	4	0.9	405	90.4
GACO5	4	0.9	409	91.3
KOPY	4	0.9	413	92.2
VEST	4	0.9	417	93.1
ARLU	3	0.7	420	93.7
DILE2	2	0.4	422	94.2
SPHE	2	0.4	424	94.6
TAOF	2	0.4	426	95.1
VIPE2	2	0.4	428	95.5
ZIEL2	2	0.4	430	96.0
ALLIU	1	0.2	431	96.2
AMCA6	1	0.2	432	96.4
ASCR2	1	0.2	433	96.7
ASFL2	1	0.2	434	96.9
ASTRA	1	0.2	435	97.1
ASVE	1	0.2	436	97.3
DAPU5	1	0.2	437	97.5
GABO2	1	0.2	438	97.8
GEPU5	1	0.2	439	98.0
GETR	1	0.2	440	98.2
MEAL2	1	0.2	441	98.4
MEOF	1	0.2	442	98.7
OXST	1	0.2	443	98.9
PAVI2	1	0.2	444	99.1
POAR7	1	0.2	445	99.3
SONU2	1	0.2	446	99.6
SYOC	1	0.2	447	99.8
TRDU	1	0.2	448	100.0

Appendix E-2. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Hand soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
BRIN2	40	27.6	40	27.6
AGIN2	27	18.6	67	46.2
LASE	21	14.5	88	60.7
CASE13	20	13.8	108	74.5
MEOF	10	6.9	118	81.4
POCO10	7	4.8	125	86.2
HEAN3	4	2.8	129	89.0
POPR	4	2.8	133	91.7
LAPU	3	2.1	136	93.8
ASER3	2	1.4	138	95.2
COCA5	2	1.4	140	96.6
TRDU	2	1.4	142	97.9
AGSM	1	0.7	143	98.6
MELU	1	0.7	144	99.3
ROAR3	1	0.7	145	100.0

Appendix E-3. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Svea soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POPR	40	9.1	40	9.1
SCSC	38	8.7	78	17.8
SOCA6	32	7.3	110	25.1
AGSM	31	7.1	141	32.1
ASER3	31	7.1	172	39.2
BOCU	28	6.4	200	45.6
PUPA5	27	6.2	227	51.7
AGTR	24	5.5	251	57.2
ANGE	23	5.2	274	62.4
ACMI2	19	4.3	293	66.7
SORI2	18	4.1	311	70.8
CATE6	17	3.9	328	74.7
STVI4	15	3.4	343	78.1
STSP2	13	3.0	356	81.1
ANCY	7	1.6	363	82.7
PHVI5	7	1.6	370	84.3
MELU	6	1.4	376	85.6
DILE2	5	1.1	381	86.8
LICA12	5	1.1	386	87.9
SYOC	5	1.1	391	89.1
SONU2	4	0.9	395	90.0
CIAR4	3	0.7	398	90.7
CIFL	3	0.7	401	91.3
ONMO	3	0.7	404	92.0
PAVI2	3	0.7	407	92.7
VIPE2	3	0.7	410	93.4
ALLIU	2	0.5	412	93.8
BRIN2	2	0.5	414	94.3
HEMA2	2	0.5	416	94.8
KOPY	2	0.5	418	95.2
MEOF	2	0.5	420	95.7
VEST	2	0.5	422	96.1
AMCA6	1	0.2	423	96.4
ANNE	1	0.2	424	96.6
ARLU	1	0.2	425	96.8
ASAG2	1	0.2	426	97.0
ASIN	1	0.2	427	97.3
ASSE2	1	0.2	428	97.5
ASSP	1	0.2	429	97.7
ASTRA	1	0.2	430	97.9
DAPU5	1	0.2	431	98.2
GETR	1	0.2	432	98.4
OXST	1	0.2	433	98.6
PSAR2	1	0.2	434	98.9
RACO3	1	0.2	435	99.1
ROAC	1	0.2	436	99.3
SEGL2	1	0.2	437	99.5
SPAS	1	0.2	438	99.8
ZIEL2	1	0.2	439	100.0

Appendix E-4. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Southam soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
SCAC	36	20.7	36	20.7
LEMI3	23	13.2	59	33.9
RIFLX	23	13.2	82	47.1
LETR	15	8.6	97	55.7
UTMA	15	8.6	112	64.4
ALGAE	12	6.9	124	71.3
TYGL	11	6.3	135	77.6
SPEU	8	4.6	143	82.2
CAAT2	7	4.0	150	86.2
ELPA3	6	3.4	156	89.7
RINAX	6	3.4	162	93.1
POAM8	4	2.3	166	95.4
SCFE	4	2.3	170	97.7
TYAN	2	1.1	172	98.9
CASA8	1	0.6	173	99.4
SCFL	1	0.6	174	100.0

Appendix E-5. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Parnell soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
CALA30	28	15.0	28	15.0
ELPA3	21	11.2	49	26.2
SPPE	19	10.2	68	36.4
ASHE	11	5.9	79	42.2
POAM8	11	5.9	90	48.1
CAAT2	10	5.3	100	53.5
RUME2	10	5.3	110	58.8
CASE13	9	4.8	119	63.6
SOAR2	7	3.7	126	67.4
SCFE	6	3.2	132	70.6
POPU5	5	2.7	137	73.3
CIAR4	4	2.1	141	75.4
EQLA	4	2.1	145	77.5
BIFR	3	1.6	148	79.1
ECMU2	3	1.6	151	80.7
PAVI2	3	1.6	154	82.4
VEFA2	3	1.6	157	84.0
ALAE	2	1.1	159	85.0
ANCA8	2	1.1	161	86.1
ANGE	2	1.1	163	87.2
BOAS	2	1.1	165	88.2
CAPR5	2	1.1	167	89.3
EQAR	2	1.1	169	90.4
HOJU	2	1.1	171	91.4
LYAM	2	1.1	173	92.5
PHAR3	2	1.1	175	93.6
AMAR2	1	0.5	176	94.1
AMPS	1	0.5	177	94.7
BESY	1	0.5	178	95.2
CANE	1	0.5	179	95.7
ELCO2	1	0.5	180	96.3
GLLE3	1	0.5	181	96.8
MEAR4	1	0.5	182	97.3
PHPR3	1	0.5	183	97.9
POAN5	1	0.5	184	98.4
ROPA2	1	0.5	185	98.9
SPEU	1	0.5	186	99.5
STPA	1	0.5	187	100.0

Appendix E-6. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Worthing soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POAM8	40	22.5	40	22.5
ELPA3	33	18.5	73	41.0
CALA30	17	9.6	90	50.6
AMAR2	16	9.0	106	59.6
BIFR	16	9.0	122	68.5
ASHE	12	6.7	134	75.3
ELAC	8	4.5	142	79.8
SPEU	7	3.9	149	83.7
APCA	5	2.8	154	86.5
RUST4	5	2.8	159	89.3
SCFL	4	2.2	163	91.6
LYAM	3	1.7	166	93.3
ALPL	2	1.1	168	94.4
CALA12	2	1.1	170	95.5
ROAR3	2	1.1	172	96.6
STPA	2	1.1	174	97.8
CAAT2	1	0.6	175	98.3
CASE13	1	0.6	176	98.9
LOPU3	1	0.6	177	99.4
PHAR3	1	0.6	178	100.0

Appendix E-7. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Tetonka soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
SEGL2	26	9.4	26	9.4
POAM8	24	8.7	50	18.1
AMAR2	20	7.2	70	25.3
BRIN2	17	6.1	87	31.4
AMAL	16	5.8	103	37.2
ASHE	16	5.8	119	43.0
RUST4	14	5.1	133	48.0
APCA	13	4.7	146	52.7
POPR	13	4.7	159	57.4
BIFR	12	4.3	171	61.7
CALA30	12	4.3	183	66.1
ROAR3	11	4.0	194	70.0
ELAC	10	3.6	204	73.6
ELPA3	7	2.5	211	76.2
RUCR	7	2.5	218	78.7
BOAS	6	2.2	224	80.9
LYAM	6	2.2	230	83.0
ECMU2	5	1.8	235	84.8
POPA2	5	1.8	240	86.6
ELOB2	4	1.4	244	88.1
POPE2	4	1.4	248	89.5
AMRE	3	1.1	251	90.6
AGHY	2	0.7	253	91.3
CHAL7	2	0.7	255	92.1
ECCR	2	0.7	257	92.8
EUSE5	2	0.7	259	93.5
HOJU	2	0.7	261	94.2
LOPU3	2	0.7	263	94.9
SACU	2	0.7	265	95.7
ALPL	1	0.4	266	96.0
AMROX	1	0.4	267	96.4
ARLU	1	0.4	268	96.8
CALA12	1	0.4	269	97.1
CASE13	1	0.4	270	97.5
CIAR4	1	0.4	271	97.8
HEAN3	1	0.4	272	98.2
JUIN2	1	0.4	273	98.6
POCO10	1	0.4	274	98.9
RUME2	1	0.4	275	99.3
SOAR2	1	0.4	276	99.6
TECA3	1	0.4	277	100.0

Appendix E-8. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Flom soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POPR	40	10.4	40	10.4
SOCA6	31	8.1	71	18.5
ASER3	29	7.6	100	26.1
AGSM	22	5.7	122	31.9
CATE6	22	5.7	144	37.6
ANGE	18	4.7	162	42.3
DILE2	18	4.7	180	47.0
HEMA2	15	3.9	195	50.9
BRIN2	13	3.4	208	54.3
EQLA	12	3.1	220	57.4
PAVI2	12	3.1	232	60.6
SCSC	12	3.1	244	63.7
ACMI2	11	2.9	255	66.6
PHPR3	11	2.9	266	69.5
PUPA5	10	2.6	276	72.1
ZIAP	9	2.3	285	74.4
BOCU	8	2.1	293	76.5
ANCA8	7	1.8	300	78.3
CIFL	7	1.8	307	80.2
SONU2	7	1.8	314	82.0
GABO2	6	1.6	320	83.6
SORI2	6	1.6	326	85.1
EQAR	5	1.3	331	86.4
HEHE5	5	1.3	336	87.7
ELCO2	4	1.0	340	88.8
STSP2	4	1.0	344	89.8
ASHE	3	0.8	347	90.6
LAPA4	3	0.8	350	91.4
PSAR2	3	0.8	353	92.2
AGTR	2	0.5	355	92.7
CABR10	2	0.5	357	93.2
CALA30	2	0.5	359	93.7
CIAR4	2	0.5	361	94.3
MEOF	2	0.5	363	94.8
ROAR3	2	0.5	365	95.3
SOGI	2	0.5	367	95.8
SPPE	2	0.5	369	96.3
ALST	1	0.3	370	96.6
ANCY	1	0.3	371	96.9
ARLU	1	0.3	372	97.1
CANE	1	0.3	373	97.4
DAPU5	1	0.3	374	97.7
HERI	1	0.3	375	97.9
HETU	1	0.3	376	98.2
LIPU	1	0.3	377	98.4
LYAM	1	0.3	378	98.7
MELU	1	0.3	379	99.0
MURA	1	0.3	380	99.2
MURI	1	0.3	381	99.5
PECA	1	0.3	382	99.7
VIPE2	1	0.3	383	100.0

Appendix E-9. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Hoven soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
BRIN2	23	11.2	23	11.2
ELAC	20	9.8	43	21.0
HOJU	17	8.3	60	29.3
AMAR2	14	6.8	74	36.1
POPR	13	6.3	87	42.4
SEGL2	12	5.9	99	48.3
ELPA3	11	5.4	110	53.7
RUST4	11	5.4	121	59.0
ECMU2	8	3.9	129	62.9
POAM8	8	3.9	137	66.8
HEAN3	7	3.4	144	70.2
AMAL	6	2.9	150	73.2
AMROX	6	2.9	156	76.1
CALA30	6	2.9	162	79.0
POPA2	6	2.9	168	82.0
CASE13	5	2.4	173	84.4
LASE	5	2.4	178	86.8
ROAR3	4	2.0	182	88.8
ASHE	3	1.5	185	90.2
MEOF	3	1.5	188	91.7
ARLU	2	1.0	190	92.7
BIFR	2	1.0	192	93.7
MELU	2	1.0	194	94.6
RUME2	2	1.0	196	95.6
SCSA2	2	1.0	198	96.6
AMRE	1	0.5	199	97.1
CAPR5	1	0.5	200	97.6
ELOB2	1	0.5	201	98.0
POCO	1	0.5	202	98.5
POCO10	1	0.5	203	99.0
PORA3	1	0.5	204	99.5
RUCR	1	0.5	205	100.0

Appendix E-10. Frequency of occurrence of species found on four replications (n = 10 plots per rep) of Vallers soil.

SPP	FREQUENCY	PERCENT	CUMULATIVE FREQUENCY	CUMULATIVE PERCENT
POPR	37	7.6	37	7.6
SOCA6	37	7.6	74	15.2
ASER3	31	6.4	105	21.6
CATE5	29	6.0	134	27.5
ELCO2	26	5.3	160	32.9
ASHE	23	4.7	183	37.6
CANE	22	4.5	205	42.1
PAVI2	21	4.3	226	46.4
AGSM	18	3.7	244	50.1
SONU2	17	3.5	261	53.6
ANGE	16	3.3	277	56.9
LYAS	16	3.3	293	60.2
SPPE	16	3.3	309	63.4
SOAR2	14	2.9	323	66.3
JUBA	13	2.7	336	69.0
ELPA3	12	2.5	348	71.5
SCSC	11	2.3	359	73.7
SORI2	8	1.6	367	75.4
EQAR	7	1.4	374	76.8
CALA30	6	1.2	380	78.0
ELCA4	6	1.2	386	79.3
JUTE	6	1.2	392	80.5
MUAS	6	1.2	398	81.7
ACMI2	5	1.0	403	82.8
CIFL	5	1.0	408	83.8
EQLA	5	1.0	413	84.8
STPA	5	1.0	418	85.8
VINE	5	1.0	423	86.9
APCA	4	0.8	427	87.7
CAGR3	4	0.8	431	88.5
LAPA4	4	0.8	435	89.3
LYAM	4	0.8	439	90.1
PHPR3	4	0.8	443	91.0
POAM8	4	0.8	447	91.8
POAN5	4	0.8	451	92.6
AGST2	3	0.6	454	93.2
AGTR	3	0.6	457	93.8
SCAT2	3	0.6	460	94.5
SYOC	3	0.6	463	95.1
CAPR5	2	0.4	465	95.5
GLLE3	2	0.4	467	95.9
MUME2	2	0.4	469	96.3
SOGI	2	0.4	471	96.7
ZIEL2	2	0.4	473	97.1
AMPS	1	0.2	474	97.3
ANCY	1	0.2	475	97.5
ASCA11	1	0.2	476	97.7
BOAS	1	0.2	477	97.9
BRIN2	1	0.2	478	98.2
CAAT2	1	0.2	479	98.4
CIAR4	1	0.2	480	98.6
GLST	1	0.2	481	98.8
MEOF	1	0.2	482	99.0
MURI	1	0.2	483	99.2
RACO3	1	0.2	484	99.4
RARH	1	0.2	485	99.6
SEPS2	1	0.2	486	99.8
VIPE2	1	0.2	487	100.0

APPENDIX F

SUGGESTED CHANGES IN WETLAND INDICATOR RATINGS FOR TEN PLANT SPECIES

SUGGESTED CHANGES IN WETLAND INDICATOR RATINGS FOR TEN PLANT SPECIES

Agropyron trachycaulum (AGTR)

The NWI lists this species as an obligate upland plant. While we found this species with regularity in upland soils, it was also found in two Flom plots and three Vallers plots. While this alone is not justification for reclassification, Dix and Smeins (1967) found that this species did occur, although infrequently, in the meadows of Nelson County, North Dakota. Also, Smeins and Olsen (1970) found it occurring in some stands dominated by Spartina pectinata which also had obligate hydrophytes in the stand. We would therefore propose to reclassify this species as a facultative upland plant.

Apocynum cannabinum (APCA)

The NWI plant list and USDA (1982) recognize two species of Apocynum in this area, A. cannabinum and A. sibiricum. Both species are listed by NWI as facultative. However, the Great Plains Flora Association (1986) considers them to be one species, A. cannabinum, the convention that we have used. Stewart and Kantrud (1971) consider Apocynum to be a characteristic plant of temporary wetlands. While Dix and Smeins (1967) found Apocynum to occur in both upland and wetland areas, Smeins and Olsen (1970) found it only in wetlands. In our study, we found it only on hydric soils (Vallers, Tetonka, and Worthing). In view of these studies, we propose to reclassify this species as a facultative wetland plant.

Bromus inermis (BRIN2)

This species is not listed by NWI. By default, it is therefore classified as an obligate upland species. In the present study, it was found on the following hydric soils (frequency of occurrence in parentheses): Flom (13), Hoven (23), Tetonka (17), Vallers (1). In addition, it was found in all 40 Hand soil plots and in two Svea plots. Although the Flom, Hoven, and Vallers soils are hydric, they are problem soils, as discussed in this report. The Tetonka soils are not only hydric, but are unquestionably wetland. Based on this data, we suggest that Bromus inermis be reclassified as a facultative upland species.

Carex tetanica (CATE6)

Dix and Smeins (1967) found this species only on sites that they considered to be upland. Smeins and Olsen (1970) found it to occur in both uplands and wetlands. In our study, we found this species occurring in 51 plots of Vallers and Flom soils (hydrics) and in 23 plots of Svea and Barnes soils (both solidly upland soils). Based on this information we propose to reclassify the NWI rating of facultative wetland to a rating of facultative for this species.

Cirsium arvense (CIAR4)

The NWI rates this species as a facultative upland. We found this species to occur in eight plots on hydric soils (Flom, Parnell, Tetonka, and Vallers) and in eight plots on upland soils (Barnes and Svea). Stewart and Kantrud (1971) have listed this species as a characteristic plant of temporary wetlands. We believe that due to the ubiquitous habitat of this species (see Great Plains Flora Association, 1986) and its frequent occurrence in wetlands, it should be reclassified to facultative.

Cirsium flodmannii (CIFL)

The NWI currently does not list this species, thereby inferring that it is an obligate upland plant. We found it occurring in twelve hydric soil plots (Flom and Vallers) and in seven upland plots (Barnes and Svea). Although Dix and Smeins (1967) found it only occurring on upland sites, Smeins and Olsen (1970) found that it did occur in stands dominated by Spartina pectinata, a community containing several species of obligate hydrophytes. Based on these observations, we propose to reclassify this species as a facultative upland plant.

Echinochloa muricata (ECMU2)

The NWI plant list rates this species as an obligate hydrophyte drawdown species. While it was only found in this study on hydric soils (Hoven, Parnell, and Tetonka), numerous personal observations by the authors suggest that it is not limited to disturbed hydric soils. Van Bruggen (1976) and the Great Plains Flora Association (1986), while recognizing that it prefers moist soil, state that it is frequent on any disturbed soil. We therefore propose that this species be reclassified as facultative wetland.

Juncus balticus (JUBA)

This species is rated as an obligate hydrophyte by the NWI. The data of Dix and Smeins (1967) and Smeins and Olsen (1970) indicate that this species is found on both upland and wetland sites. This fact alone is enough to cause us to propose to reclassify this species as a facultative wetland plant.

Poa pratensis (POPR)

This species is listed as a facultative upland plant by the NWI. While the data of Dix and Smeins (1967) and Smeins and Olsen (1970) do support this, we found it occurring in all 40 Flom plots and in 37 plots on the Vallers soils in the native prairie site in Deuel County. Likewise, it was found in the upland soils of the Deuel County site in about equal frequencies (Barnes - 39 plots, Svea - 40 plots). At the Beadle County sites, it was found in only four Hand (upland) plots, but on thirteen of the Hoven soil plots and on thirteen Tetonka soil plots. Based on our data, we believe that this species (at least in our area) should be reclassified as a facultative species.

Rosa arkansana (ROAR3)

This species is not listed on the NWI list and is therefore classified, by default, as an obligate upland plant. In our study, we found it occurring on the following hydric soils (frequency in parentheses): Flom (2), Hoven (4), Tetonka (11), Worthing (2). These last two soils are unquestionably wetland. In contrast, it was found in only one Hand (upland) plot. Smeins and Olsen (1970) likewise found it occurring in higher frequency in *Spartina pectinata* communities than in upland sites. This species should therefore be reclassified as, at least, a facultative upland plant.

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As part of a national study, vegetation associated with known hydric and nonhydric soils was sampled in selected prairie potholes and adjacent upland areas in Beadle and Deuel Counties in South Dakota. Weighted averages and unweighted averages were calculated for vegetation using procedures developed by T.R. Wentworth and G.P. Johnson at North Carolina State University and ecological indices from the National Wetland Plant List. All nonhydric soils supported a preponderance of upland plant species. Six of the seven hydric soils identified supported a preponderance of wetland vegetation, but two of these were in the questionable zone where supplemental information on hydrology and/or soils would be required to make a final decision. One hydric soil supported vegetation that was not significantly different from the upland soils.

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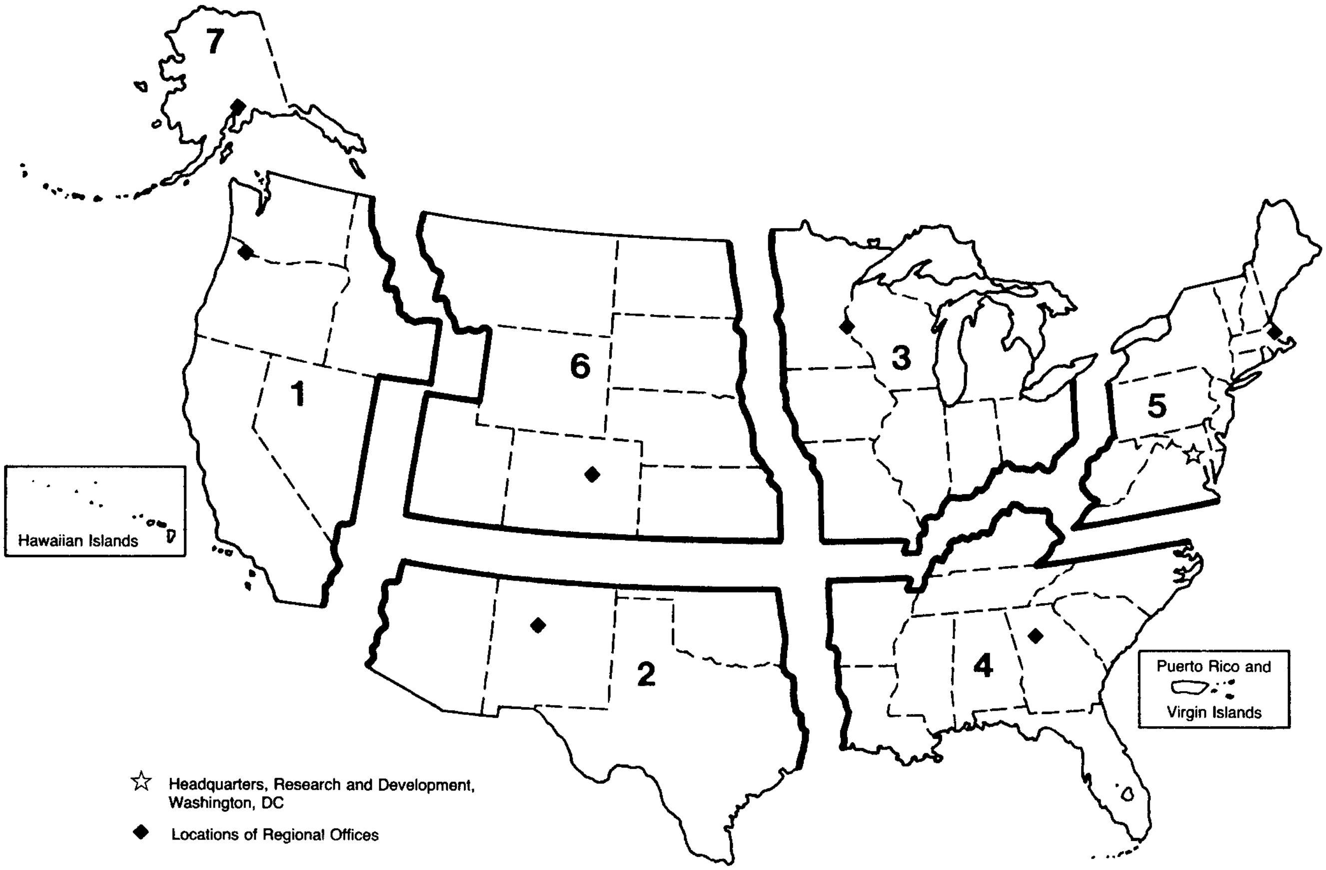

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Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
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REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

TAKE PRIDE IN AMERICA

Preserve Our Natural Resources

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.